Bulletin of the International Railway Congress Association

CONTENTS OF THE NUMBER FOR SEPTEMBER 1953.

1953 **621** .135.4, **625** .143.3 & **625** .215

Bull. of the Int. Ry. Congress Ass., No. 9, September, p. 533.

VENKATARAMAYYA (V.). — **Wear of rails on curves : a) running effects of locomotives and motor coaches with motor bogies, b) characteristics of track-laying on curve and details of the rolling stock liable to cause premature wear of the rails, c) results of the investigations made and proposed remedies. Use of rail-lubrication processes.** (Question 10, 16th Congress.) Report *(America (North and South), Australia (Commonwealth of), Burma, Ceylon, Denmark, Egypt, Finland, India, Indonesia, Irak, Iran, Republic of Ireland, New Zealand, Norway, Pakistan, South Africa, Sweden and the United Kingdom of Great Britain and Northern Ireland and the territories for whose international relations the United Kingdom is responsible).* (10 000 words, tables & figs.)

1953 **385** .4

Bull. of the Int. Ry. Congress Ass., No. 9, September, p. 573.

ADAMSON (Bengt). — **Determination of the principles and functional organisation of a railway system. Simplification and retrenchment of the administration of railways.** (Question 8, 16th Congress.) Report *(America (North and South), Australia (Commonwealth of), Burma, Ceylon, Denmark, Egypt, Finland, India, Indonesia, Irak, Iran, Republic of Ireland, New Zealand, Norway, Pakistan, South Africa, Sweden and the United Kingdom of Great Britain and Northern Ireland and the territories for whose international relations the United Kingdom is responsible).* (17 000 words, tables & figs.)

1953 **656** .254

Bull. of the Int. Ry. Congress Ass., No. 9, September, p. 615.

HEARN (S.G.) & FRASER (J.H.). — **Radiophonic communications in railway working.** (Question 5, 16th Congress.) Report *(America (North and South), Australia (Commonwealth of), Burma, Ceylon, Denmark, Egypt, Finland, India, Indonesia, Irak, Iran, Republic of Ireland, New Zealand, Norway, South Africa, Sweden and the United Kingdom of Great Britain and Northern Ireland and the territories for whose international relations the United Kingdom is responsible) (to be continued).* (16 000 words, tables & figs.)

1953 **385** .113 (44)

Bull. of the Int. Ry. Congress Ass., No. 9, September, p. 655.

New books and publications. — **Activité et productivité de la S.N.C.F. en 1952** *(The activities and productivity of the S.N.C.F. in 1952).* (300 words.)

1953 **625** .28

Bull. of the Int. Ry. Congress Ass., No. 9, September, p. 655.

New books and publications. — COCK (C.M.) : **Motive power for railways.** (300 words.)

1953 **621** .13 (02

Bull. of the Int. Ry. Congress Ass., No. 9, September, p. 656.

New books and publications. — **Henschel-Lokomotiv Taschenbuch** *(Henschel pocket locomotive book).* (300 words.)

MONTHLY BULLETIN

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CONTENTS OF THE NUMBER FOR SEPTEMBER 1953.

CONTENTS	Page.
I. **Wear of rails on curves : a) running effects of locomotives and motor coaches with motor bogies, b) characteristics of track-laying on curve and details of the rolling stock liable to cause premature wear of the rails, c) results of the investigations made and proposed remedies. Use of rail-lubrication processes.** (Question 10, 16th Congress.) Report *(America (North and South), Australia (Commonwealth of), Burma, Ceylon, Denmark, Egypt, Finland, India, Indonesia, Irak, Iran, Republic of Ireland, New Zealand, Norway, Pakistan, South Africa, Sweden and the United Kingdom of Great Britain and Northern Ireland and the territories for whose international relations the United Kingdom is responsible)*, by V. VENKATARAMAYYA	533
II. **Determination of the principles of geographical and functional organization of a railway system. Simplification and retrenchment of the administration of railways.** (Question 8, 16th Congress.) Report *(America (North and South), Australia (Commonwealth of), Burma, Ceylon, Denmark, Egypt, Finland, India, Indonesia, Irak, Iran, Republic of Ireland, New Zealand, Norway, Pakistan, South Africa, Sweden and the United Kingdom of Great Britain and Northern Ireland and the territories for whose international relations the United Kingdom is responsible)*, by Bengt ADAMSON	573

CONTENTS *(continued)*.	Page.
III. **Radiophonic communications in railway working.** (Question 5, 16th Congress.) (Report *(America (North and South), Australia (Commonwealth of), Burma, Ceylon, Denmark, Egypt, Finland, India, Indonesia, Irak, Iran, Republic of Ireland, New Zealand, Norway, South Africa, Sweden and the United Kingdom of Great Britain and Northern Ireland and the territories for whose international relations the United Kingdom is responsible) (to be continued)*, by S.G. HEARN and J.H. FRASER	615
IV. NEW BOOKS AND PUBLICATIONS	
Activité et productivité de la S.N.C.F. en 1952 *(The activities and productivity of the S.N.C.F. in 1952)*	655
Motive power for railways, by C.M. COCK	655
Henschel-Lokomotiv Taschenbuch *(Henschel pocket locomotive book)*	656

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OF THE

Permanent Commission of the International Railway Congress Association

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An edition in French is also published.

Vol. XXX. — No. 9. September 1953.

BULLETIN
OF THE
INTERNATIONAL RAILWAY CONGRESS
ASSOCIATION
(ENGLISH EDITION)

[621 .135 .4, 625 .143 .3 & 625 .215]

INTERNATIONAL RAILWAY CONGRESS ASSOCIATION

16th SESSION (LONDON, 1954).

QUESTION 10.

Wear of rails on curves :

a) running effects of locomotives and motor coaches with motor bogies;

b) characteristics of track-laying on curve and details of the rolling stock liable to cause premature wear of the rails;

c) results of the investigations made and proposed remedies. Use of rail-lubrication processes.

REPORT

(America (North and South), Australia (Commonwealth of), Burma, Ceylon, China, Denmark, Egypt, Finland, India, Indonesia, Irak, Iran, Republic of Ireland, New Zealand, Norway, Pakistan, South Africa, Sweden and the United Kingdom of Great Britain and Northern Ireland and the territories for whose international relations the United Kingdom is responsible),

by V. Venkataramayya, B.A., B.Sc(Hons), (Lond.), A.M.I.E.,

Central Standards Office for Railways, (Ministry of Railways), New Delhi (India).

FOREWORD.

The questionnaire was drawn up to elicit information on the form of wear of rails on curves, the relationship between the degree of wear and the radius of curve, axle loads, kind of traffic and total tonnage; the adverse effect of electric locomotives and rolling stock with motor bogies; the special features of track laying on curves, and the various remedial measures adopted to reduce the wear of rails on curves. Copies of questionnaire were circulated to 38 Railway Administrations from whom at the time of compiling the report, only 5 fully detailed replies have been received. Part replies have been received from 3 Railway Administrations, which are also reviewed in this report.

The answers furnished by the British Railways to part 1 of the questionnaire is mainly applicable to the electrified area of the Southern Region but may be considered as typical of other regions. The information given by the Central Railway of the Indian Government Railways is likewise applicable to that Railway but is also typical of other Indian Government Railways. The answers supplied by the Association of American Railroads are based on the general practices of the American railroads but they have stated that there is considerable diversity between the individual railroads.

On the question of wear of rails on curves, it seems that very little statistical data is maintained by the Railway Administrations and the information available does not generally warrant any quantitative deductions.

Preliminary data.

Question 1. — *Characteristics of the track :*

Please give the information asked for in table 1 appended, accompanying this if necessary by additional details.

The details are given in table 1.

The usual minimum radius on Standard (S.G.) or Broad gauge main lines varies from 660 ft. to 2 865 ft. and on Metre gauge (M.G.) from 490 ft. to 2 865 ft. depending on the nature of the terrain, kind of traffic and maximum speeds.

In exceptional cases, also in yards and stations the minimum radius varies from 383 ft. to 800 ft. on S.G. and from 295 ft. to 360 ft. on M.G.

The gauge is generally widened on sharp curves, the extent of widening depending on the gauge, S.G. or M.G., the radius of curve and the rigid wheelbase of the rolling stock.

The superelevation or cant is based on the average speed, but at the maximum speed the deficiency of cant is not to exceed a certain value. The rate of increase or decrease of cant is again limited in order to ensure safety.

Many of the Administrations use more than one section of rail. No differentiation has been made between curved portion and straight portion of track regarding the use of a particular section of rail.

Question 2. — *Characteristics of the rolling stock :*

Please give the information asked for in table 2 appended, accompanying this if necessary by further details.

For each category of vehicles, please select those of the greatest interest as regards the question covered by the present report.

The information is given in table 2. Having regard to the question covered by the present report, the Railway Administrations have given details mostly of electric locomotives and motor coaches, since the data furnished by them in regard to other parts of the questionnaire relate mainly to electrified sections. The South African Railways and Harbours have however given particulars of steam locomotives and other rolling stock which are incorporated in the table. The Association of American Railroads have not given particulars of rolling stock as there is considerable diversity between their railroads and the Association operates no equipment.

Question 3. — *Please give the characteristics of the steels used (especially their breaking strength in kg/mm²) :*

— for the rails;

— for the tyres.

Rails are generally manufactured of high carbon steel, the percentage of carbon varying from 0.5 to 0.7. On the British, South African and Indian Railways, medium manganese rails are also used. In the medium manganese quality rails, the carbon content is about 0.1 % lower and the manganese content is about 1.0 to 1.4 %. On the American railroads, high carbon steel rails are almost exclusively used (except for small scale trials with alloy steels) and the percentage of carbon is slightly higher being about 0.6 to 0.8.

The ultimate tensile strength of high carbon rail steel varies from 70.0 to 86.7 kg/mm² (44.44 t to 55.04 t per sq. inch). The same minimum tensile strengths are prescribed for medium manganese steel but without upper limits. The rail steel of the American railroad, has higher ultimate strength, varying from 84.0 to 98.0 kg/mm² (53.33 t to 62.2 t per sq inch). The minimum elongation is stated to be 12.0 % on 50.8 mm (2″) long tensile test piece for lower ultimate strength steel and 10.0 % for higher ultimate strength steel.

The tyre steel has higher tensile breaking strength, that of motor bogie tyres being 99.2 to 108.7 kg/mm² (63.29 t to 69 t per sq. inch) and of trailer bogie tyres being 78.7 to 88.2 kg/mm² (49.96 t to 56 t per sq. inch).

Question 4 :

a) *Below what radius of curve does lateral wear of the rails on the outer-rail become noticeable? Please state if this be so on those of your lines on which you have noted a particularly marked wear of the rails on curves.*

The worst cases of lateral wear are generally found on curves of less than 2 000 ft. (610 m) radius where there is a large cant deficiency. On the American railroads, the lateral wear is noticeable on curves of less than 5 730 ft. (1 750 m) radius.

The lateral wear is particularly noticeable with electric motor bogies, even on a straight track where the hunting movement of the bogies results in intermittent side wear of the rails.

b) *Have you noticed any lateral wear resulting in the rails becoming chamfered off?*

On account of lateral wear, the gauge face of the outer rail on curves gets chamfered. Profiles giving the details of chamfer are shown under question 6.

c) *Have you noticed wear of the running surface accompanied by an increase in the inclination thereof?*

The wear on the running surface of the outer rail tends to increase the inclination thereof, but to a very small extent and is not noticeable.

Question 5. — *What form of wear takes the rails on the inside of the curve?*

The inside rail on the curve wears off practically parallel to the base. In many cases the table of the rail gets flattened and metal flow results in lips being formed at the sides.

Question 6 :

a) *Characteristic elements of the rail section showing the greatest wear when taken out of service :*

—		*Rail on outside (Large radius)*	*Rail on inside (Small radius)*
Lateral wear	*Maximum width of wear . .*	8 to 22 mm (5/16″ to 7/8″)	Nil.
	Inclination to the axis of the rail to the straight line . . Joining the edges of the chamfer	24° — 38°	Not found
Wear of the running surfaces	*Height on the axis of the rail*	9 to 15 mm (3/8″ to 19/32″)	
	Inclination to the axis of the rail	Practically parallel	to base of rail

TABLE

WEAR OF RAILS

I. CHARACTERISTICS

Railway or line	Minimum Radius		Gauge of the track			Supere
	Usual	Excep-tionally	On the straight & Rad :	R lying between	R	Formula
1	2	3	4	5	6	7
Central Railway (Indian Govt. Rlys) S.G. 5′ 6″	2856 ft. except in ghat sections 1146 ft.	729 ft.	On straight and up to 4° curve exact gauge.	Exceeding 4° — 1/4″ slack.	—	$C = \frac{GV^2}{1.25R}$ C = cant in inches V = 45 m.p.h. for Main line & 30 m.p.h. Ghat Section For electrified Section V = 55 m.p.h. G = Gauge in ft. R = Radius in ft.
M.G. 3′ 3 3/8″	2865 ft. except in station Yards 716 ft.	360 ft.	On straight and up to 6° curve exact gauge.	From 6° to 10° — 1/4″ slack	Exceeding 10° — 1/2″ slack.	$C = \frac{GV^2}{1.25\ R}$ where V = 35 m.p.h.
British Railways S.G. 4′ 8 1/2″ 1.435 m	660 ft. (201 m)	462 ft. (141 m)	On straight and up to 660 ft. radius exact gauge	Between 660′ & 462′ radius gauge is 1/4″ slack.	Between 462 ft. & 363 ft. radius gauge is 1/2″ slack.	$E + D = \frac{.06V^2}{R}$ E = Cant in inches. D = allowable deficiency of cant in inches V = speed in m.p.h. R = Radius of curve in chains of 66 ft.
London Transport Executive S.G. 4′ 8 3/8″	792 ft.	—	On straight 4′ 8 3/8″	On curves of radius greater than 660 ft. — 1/8″ slack.	On curves less than 660 ft. radius — 1/4″ slack	$E = .052\ \frac{V^2}{R}$ E = Cant in inches. V = Average speed in m.p.h. and R = Radius in chains of 66 ft. allowable cant deficiency = 2 1/2″

)N CURVES
)F THE TRACK

vation	Parabolic transition		Rails		Dimensions		
Maximum	Length	Max. slope of the super-elevation	Weight per m or per yard	Type Vignole bull-headed or grooved	Height	Width of head	Width of flange
8	9	10	11	12	13	14	15
5″ and 6 1/2″ in electrified area	The length of transition depends upon the amount of shift & the amount of cant and the distance in which it is run out.	1 in 360	90 lbs/yd 100 lbs/yd 82 lbs/yd 75 lbs/yd	Vignole Bull headed Bull headed Vignole	5 5/8″ 5 29/32″ 5 1/2″ 5″	2 5/8″ 2 3/4″ 2 3/8″ 2 3/8″	5 3/8″ 2 3/4″ 2 3/8″ 4″
4″	—do—	1 in 360	60 lbs/yd	Vignole	4 1/2″	2 1/4″	4 5/16″
Max. cant = 6″ (155 mm) Max. cant deficiency D = 3 1/2″ for main lines & 2 1/2″ for secondary lines or turnouts where there is no cant & decrease to 2″ and 1″ where there is 6″ cant	L = .65 EV ft. L = .65 DV ft. L = 25 E ft. E & D in inches V = m.p.h. & L in ft.	1 in 300	109 lbs/yd (54.51 kg/m) 98 lbs/yd (48.62 kg/m) 95 lbs/yd (47.13 kg/m)	Vignole Vignole Bull headed	6 1/4″ 5 5/8″ 5 23/32″	2 3/4″ » »	5 1/2″ » 2 3/4″
6″ on curves of 1320 ft. radius and over. 5 1/2″ on curves of radius less than 1320 ft.	L = 1.52 EV E = cant in inches V = speed m.p.h. L = length in ft.	1 in 480	95 lbs/yd	Bull headed	5 23/32″	2 3/4″	2 3/4″

TABLE I

WEAR OF RAILS

I. CHARACTERISTICS

Railway or line	Minimum radius		Gauge of the track			Supere
	Usual	Excep-tionally	On the straight & Rad :	R lying between	R	Formula
1	2	3	4	5	6	7
Association of American Railroads (4′ 8 1/2″)	955 ft.	383 ft.	On straight and up to 6° — exact gauge	On curves sharper than 6° gauge is widened depending on the type of rolling stock.	—	Superelevation determined so that deficiency of cant does not exceed 3″
Egyptian State Rlys. S.G. (1.435 m) Cairo-Alex	600 m	—	1.435 m	—	—	—
Cairo-Shellai	400 m	—	1.435 m	—	—	—
Aalborg Privatbaner Denmark S.G. (1.435 m)	300 m	157 m	1.435 m	For curves of radius 700 to 500 m gauge is widened by 5 mm. 500 to 400 m radius gauge is widened by 10 mm.	For curves of radius 400 to 300 m gauge is widened by 15 mm.	$E = \frac{8V^2}{R}$
South African Rlys M.G. 3′ 6″ (1.067 mm) Electric-steam lines Max. 88.5 km/h	210 m	150 m	On curves of radius larger than 450 m the gauge is exact.	On curves of radius less than 450 m but greater than 210 m gauge widened by 6 to 12 mm.	On curves of radius less than 210 m gauge widened by 19 to 22 mm.	According to speeds and gradients
Single steam lines max. 72.4 km/h	»	»				
Single steam line Max. 56.3 km/h	150 m	90 m				
N.G. 2′ 0″ (610 mm) Single steam line Max. 40.2 km/h	60 m	—	On curves of radius larger than 305 m gauge is exact.	On curves of radius less than 305 m but larger than 183 m gauge is widened by 6 mm.	On curves of radius less than 183 m gauge is widened by 12 mm.	—do—

ontinued).

CURVES

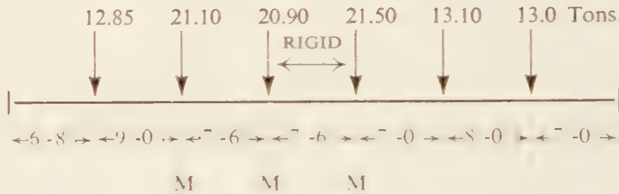
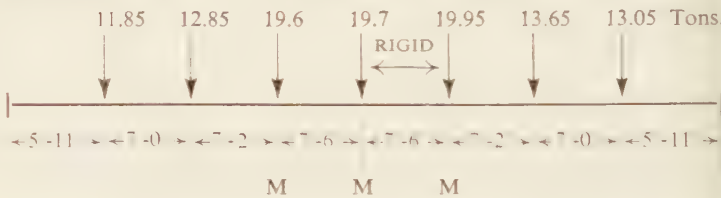
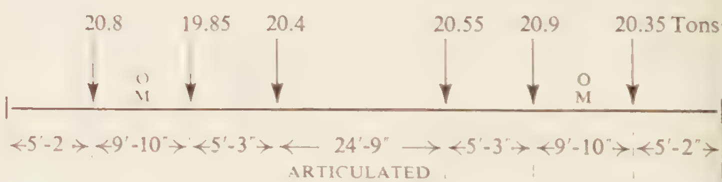
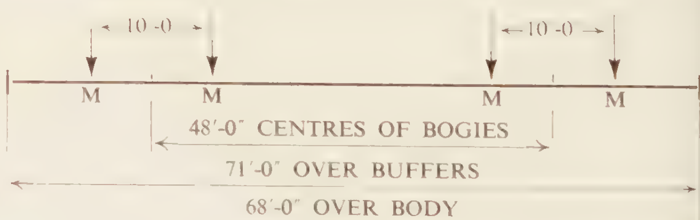
THE TRACK

tion	Parabolic transition		Rails		Dimensions		
Maximum	Length	Max. slope of the super-elevation	Weight per m or per yard	Type Vignole, bull-headed or grooved	Height	Width of head	Width of flange
8	9	10	11	12	13	14	15
/aries from 5″ to 6″ On tracks aving traffic one direction ll about the ame speed a ax. of 8″ is permissible.	L = 1.17 EV E = Cant in inches. V = Max. train speed in m.p.h. L = Length in ft.	—	90 lbs/yd 100 lbs/yd 115 lbs/yd 132 lbs/yd 133 lbs/yd	Vignole » » » »	5 5/8″ 6″ 6 5/8″ 7 1/8″ 7 1/16″	2 9/16″ 2 11/16″ 2 23/32″ 3″ 3″	5 1/8″ 5 3/8″ 5 1/2″ 6″ 6″
13 mm	—	$\frac{1}{600}$	54 kg/m	Vignole	158.75 mm	73.07 mm	152.4 mm
13 mm	—	$\frac{1}{600}$	46 kg/m	»	140 mm	58 mm	112 mm
100 mm	—	—	22.4 kg/m 23.5 kg/m 24.39 kg/m 27.5 kg/m 31.6 kg/m 32 kg/m 33.4 kg/m	Vignole » » » » » »	95 mm 116 mm 115 mm 115 mm 129 mm 118 mm 137 mm	51 mm 51 mm 53 mm 58 mm 58 mm 57 mm 58 mm	89 mm 89 mm 90 mm 100 mm 105 mm 107 mm 105 mm
127 mm	61.5 m	1 in 480	47.6 kg/m	Vignole	149.2 mm	68.2 mm	127.0 mm
114 mm			40.2 kg/m	»	127.0 mm	63.5 mm	—do—
102 mm			30.3 kg/m	»	114.3 mm	57.2 mm	109.5 mm
25.4 mm	30.7 m	1 in 480	22.3 kg/m 17.4 kg/m	—	95.2 mm 82.6 mm	50.0 mm 44.4 mm	95.2 mm 82.6 mm

TABLE

WEAR OF RAILS

II. CHARACTERISTICS

RAILWAY LINE	GAUGE	TYPE OF VEHICLE	DIAGRAMS OF VEHICLES
Central Railway (Indian Govt. Railway)	S. G. (5′-6″)	Electric locomotive	
			
			
		Electric rail motor coach	

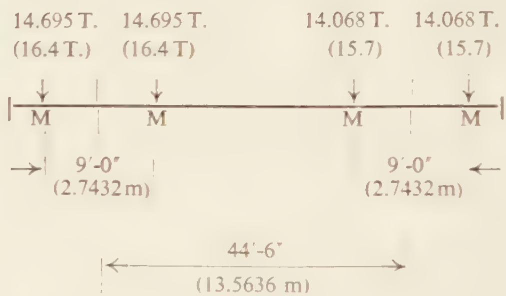
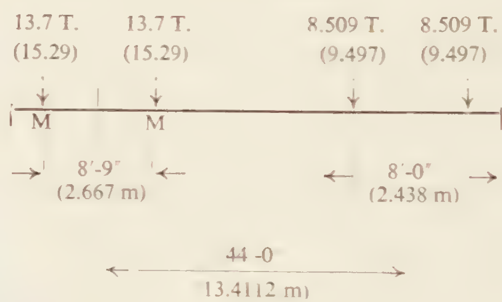
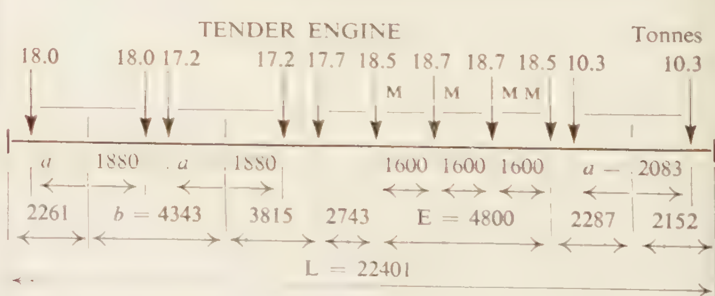
N CURVES
F ROLLING STOCK

NUMBER OF ENGINES		POWER TOTAL	TRACTIVE EFFORT	AXLES			RUNNING SPEED		REMARKS
EAT	TRACTION MOTORS	H.P.	TONNES	WHEEL SEAT	FLANGE THICK	WHEEL DIA :	FASTEST	SLOWEST	
—	6	360 H. P. per motor	9.8 at 1 hour rating		1 1/8″	5′-3″	65 m.p.h.	35 m.p.h.	
—	3 twin	750 H. P. per twin motor	10.6 at 1 hour rating		1 1/8″	6′-2″	65 m.p.h.	35 m.p.h.	
—	4	650 H. P. per motor	25.4 at 1 hour rating		1 1/8″	4′-0″			
—	4	275 H. P. per motor			1 1/8″	3′-7″	65 m.p.h.	40 m.p.h.	

TABLE 2

WEAR OF RAILS

II. CHARACTERISTICS

RAILWAY LINE	GAUGE	TYPE OF VEHICLE	DIAGRAMS OF VEHICLES
Brighton main line electrification of the Southern Region British Railways	S. G.	Electric rail motor coach	
			
South African Railways and Harbours	M.G. 3′-6 =1067mm	Steam engine (15 F)	

ntinued)

CURVES

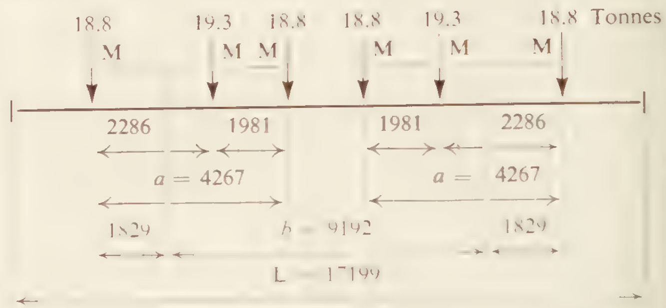
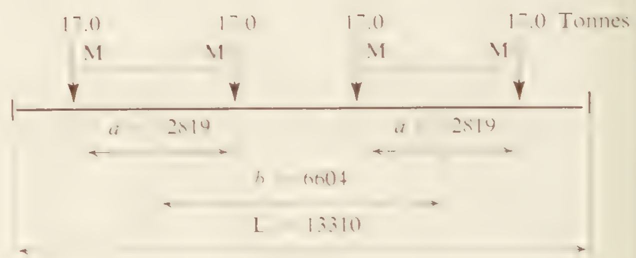
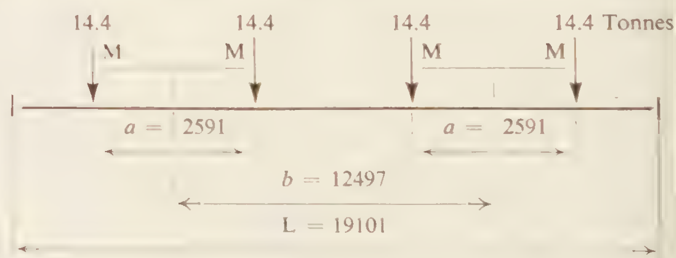
ROLLING STOCK

UMBER OF NGINES		POWER TOTAL	TRACTIVE EFFORT	AXLES			RUNNING SPEED		REMARKS
AT	TRACTION MOTORS	H.P.	TONNES	WHEEL SEAT	FLANGE THICK.	WHEEL DIA :	FASTEST	SLOWEST	
-	4	225 H.P. per motor at one hour rating (228 cheval vapeur)	1.061 at 1 hour rating	7 15/16 dia. × 7 1/2″ lg. (20.161 cms × 19.05 cms)	1 1/8″ 2.8675 cms	3′-7″ (1.092 m)	52.5 m.p.h. (84.4 km/h)		
-	2	275 H. P. per motor at one hour rating (279 cheval vapeur)	1.746 at 1 hour rating	7 15/16 dia. × 7 1/2″ lg. (20.161 cms × 19.05 cms)	1 1/8″ 2.8675 cms	3′-7″ (1.092 m)	—	33.87 m.p.h. (54.55 km/h)	
	2 cylinders 4 axles driver		19.21 (75 %)	114 mm	25 mm	Front truck 762 mm drivers 1524 mm others 864	88.5 km/h	56.3 km/h	Not much used on sections for which rail wear is given.

TABLE

WEAR OF RAIL

II. CHARACTERISTIC

RAILWAY LINE	GAUGE	TYPE OF VEHICLE	DIAGRAMS OF VEHICLES
South African Railways and Harbours	M.G. 3′-6″ = 1067mm	Electric loco (3 E)	
		Electric loco (1 E)	
		Electric motor coach (REEF)	

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CURVES

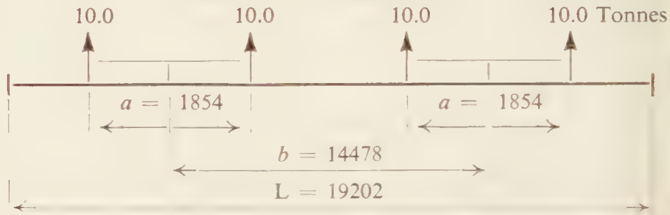
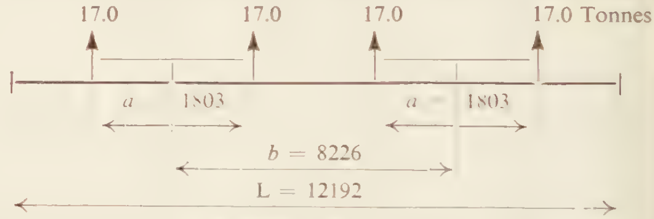
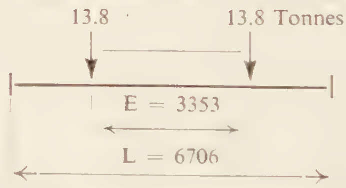
ROLLING STOCK

UMBER OF NGINES		POWER TOTAL	TRACTIVE EFFORT TONNES	AXLES			RUNNING SPEED		REMARKS
AT	TRACTION MOTORS	H.P.		WHEEL SEAT	FLANGE THICK	WHEEL DIA :	FASTEST	SLOWEST	
				mm	mm	mm	km/h	km/h	
-	6	2700 (1 hour)	—	114	25	1219	104.6	56.3	Speed normally low on the relevant sections due to sharp curves.
-	4	1200	9.62	114	25	1219	72.4	56.3	See remarks above.
—	4	1148	5.02	114	25	1054	104.6	72.4	Not much used on the sections for which rail wear is given.

TABLE

WEAR OF RAI

II. CHARACTERISTIC

RAILWAY LINE	GAUGE	TYPE OF VEHICLE	DIAGRAMS OF VEHICLES
South African Railways and Harbours	M.G. 3′-6″ 1067mm	Passenger coach full	
		B. B. goods bogie truck loaded	
		Goods 2-axle truck loaded	
London Transport Executive	S. G.	Electric rail motor coach	 BOGIE WHEEL BASE IS 7′-10″ = 3′-4 1/2″ + 4′-5 1/2″
Ceylon Govt. Railway	S. G. (5′-6″)	Diesel electric rail car	

ntinued)

CURVES
.ROLLING STOCK

UMBER OF NGINES		POWER TOTAL	TRACTIVE EFFORT TONNES	AXLES			RUNNING SPEED		REMARKS
AT	TRACTION MOTORS	H.P.		WHEEL SEAT	FLANGE THICK	WHEEL DIA :	FASTEST	SLOWEST	
				mm	mm	mm	km/h	km/h	
.	—	—	—	114	25	864	104.6	56.3	The majority of passenger traffic is carried in these and similar coaches.
.	—	—	-	114	25	864	56.3	40.2	Most goods traffic is carried in these and similar trucks of lighter axle loads.
	—	—	—	114	25	864	56.3	40.2	Carries only a small part of the traffic on the relevant sections.
	—	266 H. P. per motor	—	M 6.63″ dia. T 6.19″ dia.	1 1/8″	3′-0″	Average	22.5 m.p.h.	
.	2	180 H. P. per motor	—	6″ dia.	—	2′-10″	55 m.p.h.		

The London Transport Executive and the Association of American Railroads consider that it is not possible to lay down specific limits for wear. The rails are renewed for a wide variety of reasons and it has to be left to the judgement of local maintenance officers. The section of rail in relation to axle loads and speeds, will also have to be taken into consideration;

b) *Please complete your reply by drawings or photographs of sections of used rails from curves compared with those of unworn rails. In each case, please mark the vertical centre line of the track and indicate :*

- *the inclination at which they were laid;*
- *the radius of the curve;*
- *the number of years the rail has been in service;*
- *the heaviest axle loads;*
- *the kind of traffic : number of express trains and heavy trains and pairs of wheels running over them daily on the average throughout the year, average annual tonnage, etc.*

Profiles of two typical sections of worn rail heads, obtained from British Railways are reproduced below. The data required is given in the figures and the original profile is also marked. These rails have been removed from track before rail lubrication was introduced. The rails in every case are laid at an inclination of 1 in 20.

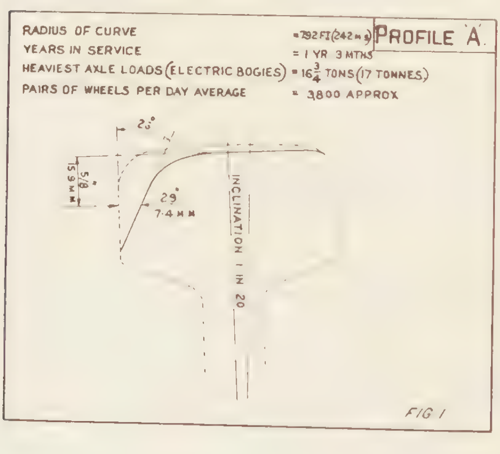


FIG 1

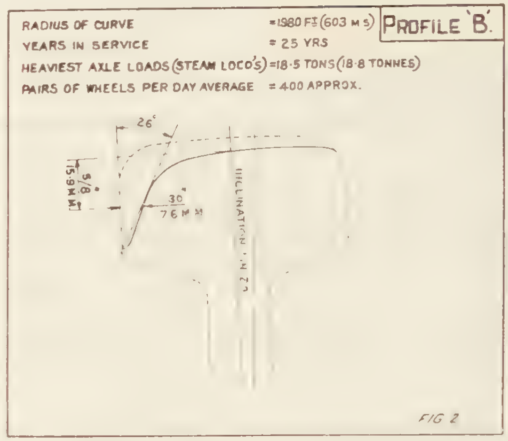


FIG 2

On the South African Railways the life of the outer rail may be only 2 years on a curve of 150 m radius, with an annual traffic of 10 000 000 tons, a maximum axle load of 16.4 tons, approximately 40 trains per day, of which the great majority are heavy and express trains.

PART I.

RUNNING EFFECTS ON RAILWAYS OF LOCOMOTIVES AND RAIL MOTOR-COACHES WITH MOTOR BOGIES.

Question 7 :

a) *How many years is it since you replaced steam traction by electric traction or by heat engines (Diesel or compression ignition engines with electric or mechanical drive)? Has electric traction been used on some of your lines ever since they were built?*

The answer is obviously different for each railway. On the Central Railway (India), electric traction was first introduced in 1924. This branch has been relaid in the year 1945-46. On the British Railways, the first change over from steam to electric traction took place in 1909. The particular stock detailed in table 2 was introduced on the Brighton line 20 years

ago. Electric trains have run exclusively on a very small number of lines since they were first built, but by far the majority of lines were used for steam locomotives hauled trains before electrification and in most cases are still occasionally run on by steam trains.

The tube lines of the London Transport Executive have been utilized for electric traction since their construction mainly in the decade before and the decade after the commencement of the 20th century. On cut and cover lines electrification began in 1905. On the South African Railways, electric traction has been used for 25 years and on some sections for about 20 years since they were built.

b) *How many years have locomotives or rail motor coaches with motor bogies been running?*

Railway	Electric locomotives	Motor coaches with motor bogies
Central Railway (India)	20 years	28 years
British Railways	—	44 years
London Transport Executive	—	60 years
American Railways	—	35 years
South African Railways & Harbours	20 years	25 years
Ceylon Goverment Railway	—	15 years
Aalborg Privatbaner Denmark	5 years	18 years

Question 8 :

a) *Are the effects of motor bogies particularly bad on curves?*

Motor bogies have generally been found to produce more wear on curved track than on straight track. American railroads have not however noticed any particularly bad effect of motor bogie on curves.

b) *Have you compared the effects on curves of bogies with different characteristics :*

- *bogies with 2 (or possibly 3) motor axles;*
- *bogies with one motor axle, and one carrying axle,*
- *bogies without any motor axle?*

Detailed comparisons have not been made.

c) *Does the running of locomotives, rail motor coaches or railcars with motor bogies result in more rapid wear of the rails on curves than running :*

- *locomotives with coupled axles behind a carrying bogie or bissel truck;*
- *trailer bogie vehicles;*
- *trailer vehicles with a large rigid wheelbase;*
- *railcars with a large rigid wheelbase?*

Adequate stastistics have not been maintained by the Railway Administrations and no comparisons have been made.

d) *Please classify if possible, the vehicles running or which have run on your lines according to the order in which they affect wear of the rails on curves (as ascertained or merely presumed) starting with the worst.*

None of the railways have sufficient information to classify the vehicles in the order in which they affect wear of the rails on curves. The Central Railway (India) have however observed from experience (no definite tests have been made) that the order may be as follows :

i) motor coach with motor bogies;

ii) articulated double bogie type freight locomotive;

iii) electric passenger locomotive with 2-6-4 wheel arrangement.

Question 9 :

a) *Do the worn surfaces of the rails and wheels retain their polish?*

The rails and wheels retain their polish provided the traffic density is sufficiently high to prevent corrosion and the vehicle is in regular use. The type of brake block used may also affect the brightness of the polish.

b) *Does the passage of the pairs of wheels result in any seizing? Does this seizing show itself:*

— by a grating noise?

— by small particles of metal falling onto the foot of the rails?

What appears to cause this seizing?

Are there any points at which the wear is particularly marked? Does the occurrence of these points appear to coincide with a hunting movement of the bogies?

Seizing occurs sometimes, on sharp curves accompanied by a grating noise and falling off of small particles of metal. The grating noise may probably be due to vibration caused by the rubbing of the wheel flange against the rail.

There are points on the rail where the wear is particularly marked due to the hunting movement of the bogies causing an intermittent side wear.

Question 10 :

a) *Please describe, adding drawings or photographs if possible, the connections between the bogies and the frame and the centering devices (springs or gravity) countering the rotation of the bogies. How great is the centering force (initial and final tension of the springs...).*

In the case of motor coaches with motor bogies, no centering device countering the rotation of the bogie is provided. On the Central Railway (India), bogie centering devices are fitted to the freight and passenger locomotives. On the latter, the centering device consists of spring control with a centering force of 4 tons at the end.

On the South African Railways, electric locomotives have bearing surfaces near the sides of the bogies and a spring controlled connection between the bogies as shown below :

FIG 3

b) *In the case of 4 wheeled bogies, is the bogie centre in the middle of the wheelbase?*

The bogie centre of 4 wheeled bogies is generally in the middle of the wheelbase. In the case of the latest stock of motor bogies of the London Transport Executive however the bogie centre is slightly offset to give more weight on the driving axle, there being one driving axle per bogie.

c) *If you have any six wheeled bogies, is the bogie centre in the middle of the wheelbase or between the first and second pairs of wheels?*

The practice varies on different railways. On the American railroads, the bogie centre is in the middle. On the South African Railways, it is between the first and second axles. On the Central Railway (India), six wheeled bogies are provided only on the freight locomotives and the bogie centre is at the end of the bogie, the body of the locomotive providing articulation between the bogies.

d) *Have you had to reduce the force exerted by the centering devices in order to facilitate inscription through*

curves and reduce lateral wear of the rails and tyres?

Only on the Central Railway (India), attempts have been made to reduce the friction between bogie slide and bogie of the passenger locomotives. On some of the six wheeled bogies of the South African Railways, additional friction supports for the main body have been introduced near the ends of the bogies to eliminate hunting.

Question 11. — *Please give details and the results of your observations concerning the position and method of suspension of the heat engines and electric motors and on the type of drive used.*

The traction motors of motor coaches are usually axle hung and nose suspended with straight spur gears and pinions. On the freight and passenger locomotives of the Central Railway (India) the traction motors are frame mounted.

Question 12 :

a) *To what causes do you attribute the greater wear of rails due to the motor bogies?*

The greater wear of rails due to motor bogies is attributed to :

i) the amount of unsprung weight of the axles;

ii) the low centre of gravity of the vehicle;

iii) the small diameter of the heavily loaded wheels;

iv) high rates of acceleration and deceleration and higher average speeds;

v) unsymmetrical application of torque;

b) *In particular have you noted any relation between the transversal reaction of the rail on the one hand and the axle loads on the other as regards the tractive effort and the centering force of the bogies? Have you obtained any deductions therefrom regarding the lateral wear of rails?*

(Your report can be based with advantage on theoretical considerations.)

With heavier axle loads and larger centering force, greater transversal reaction of the rail can be caused, since greater transversal reaction will be required to counter the centering force, and heavier axle load will make that possible. The increase in tractive effort will increase the load on some axles and decrease the load on others so as to balance the moment in the vertical plane. The increase in the tractive effort or centering force may therefore result in increased transversal reaction and greater lateral wear of rails.

Question 13. — *Has consideration of the wear led you to reduce the speed through certain curves?*

(The amount of such a reduction, in terms of the radius and superelevation.)

There has not been any instance where speed has been reduced on curves on consideration of wear of rails. Speeds are normally limited by passenger comfort and safety. Excessive wear of one rail compared to the other is usually corrected by adjusting the superelevation.

PART II.

CHARACTERISTICS OF TRACK-LAYING ON CURVES AND DETAILS OF THE ROLLING STOCK LIABLE TO CAUSE PREMATURE WEAR OF THE RAILS.

A. — Laying the track on curves.

Question 14. — *What observation have you to make on the characteristics of laying track on curves which may lead to premature wear of the rails, in particular.*

Influence of the layout :

a) *the wear being the greater as the radius of curve is the smaller, have you established any relation between the degree of wear and the radius of curve?*

It is generally considered that the rate of wear varies inversely as the radius of the curve. The available data are insufficient to establish a definite quantitative relation between the degree of wear and the radius. A sample investigation carried out by the London Transport Executive has shown that the rate of wear on the straight is about doubled on a 660 ft. radius curve and about trebled on a 330 ft. radius curve: the curves to which the observations relate were however undercanted compared to the present standards of superelevation. A graph showing the relation between the rate of wear and the radius of curve prepared by the South African Railways is reproduced in plate 1.

b) *Do irregularities in the curvature lead to considerably more wear than that experienced in the case of a regular curve of the same radius?*

Can you give the importance in the variation of the versines over and above which the amount of wear increases appreciably?

Railways have not analysed in detail the effect of irregularities in curvature on rail wear. Irregularities in curvature cause rough running, with consequent increase in transversal reaction at some points, which naturally increases wear of rail at these points.

Probably a variation in versine of the order of 20 % on adjacent 30 ft. half chords is necessary to establish a local differential in rail wear but this is only an impression suggested by experience.

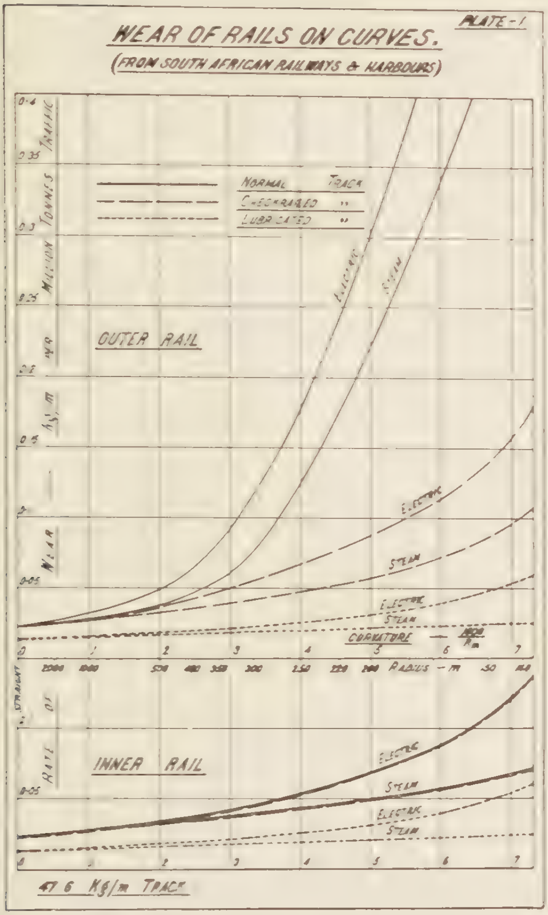
Question 15. — *Influence of the superelevation: the results on the one hand of an insufficiency, and on the other of an excess of superelevation. Is the superelevation so calculated as to assure a position of equilibrium for the fastest trains and railcars, or according to an intermediate speed of all the trains?*

What values do you consider admissible for an insufficient and for an excessive superelevation?

Excess or deficiency of superelevation (or cant) causes unequal wear on rails. Superelevation of track is calculated to give equilibrium conditions for trains of intermediate speed, providing the deficiency of superelevation for the fastest train is within the permissible limits. A maximum cant deficiency of 3″ is permitted on Broad gauge lines of the Indian Railways and on the standard gauge lines of American railroads. The London Transport Executive allows a deficiency of 2 1/2″ on their S.G. lines but most of their services operate at about the same speed and they have not found it necessary to lay down a standard for excessive superelevation. On the 3′ 6″ gauge lines of the South African Railways, an insufficient or excessive superelevation of 2″ to 2 1/2″ is considered permissible. On the 3′ 3 1/2″ (M.G.) gauge lines of the Indian Railways, a cant deficiency of 2″ is allowed.

On the British Railways, the maximum allowable deficiency of cant varies according to the class of line and actual cant, the overall maximum cant deficiency being 3 1/2″, and the values are shown in the table below:

Class of line	Max. deficiency in inches	Actual cant E (inches)						
		0	1	2	3	4	5	6
A and B	3 1/2 — 1/4 E	3 1/2	3 1/4	3	2 3/4	2 1/2	2 1/4	2
C and D & Turnouts	2 1/2 — 1/4 E	2 1/2	2 1/4	2	1 3/4	1 1/2	1 1/4	1



The reason for reducing the cant deficiency with an increase in actual cant is that track imperfections have greater influence at higher speeds.

Question 16. — *Influence of parabolic transitions :*

insufficient length;

excessive superelevation gradients;

irregularities in the curvature of the rails.

Insufficient length of transition causes more wear in the beginning of the curve apart from discomfort and high transversal force exerted on the rail.

Excessive superelevation gradients affect running safety through high vertical accelerations, and unloading of one of the wheels. On the American railroads the length of the transition is such that superelevation is attained not more than 1 1/4″ per second for fastest train. On the British Railways, the permissible rate of gain of cant and of deficiency of cant is 2 1/4″ per second for the fastest train, but their recommended value is 1 1/2″ per second. On the Central Railway (India) the length of transition is taken as the greater of the two following values :

a) $L = 3.155 \dfrac{V^3}{R}$

b) $L = 60\ C$;

where L = length of transition in ft.;
V = permissible speed in miles per hour;
R = radius in feet;
C = cant of circular curve in inches.

Irregularities in curvature cause excessive wear of rails and diminish safety on account of high transversal force.

Question 17. — *Influence of the gauge : with the same radius of curve, does the wear vary in terms of the gauge ?*

The side wear usually increases with wide gauge due to increase in the angle of attack of the wheels.

Question 18. — *Influence of defects in the inclination of the rail (turn over towards the outside).*

If the rail turns towards the outside, the gauge is widened, the angle of attack increased and more wear will result. But the effect will be small as the lateral movement cannot be great. The inclination of the rail table will also not suit the coning of the tyres and therefore the top inside edge of the rail head will be rapidly worn out.

Question 19. — *Influence of the gradients: heavy up and down gradients.*

Heavy gradients increase the wear through greater tractive effort or the braking necessary and also due to wheels slipping.

Question 20. — *Influence of the rail joints and their relative position (in line or alternating) and the way they are supported on the sleepers.*

Rail joints on curves are normally in line and they are suspended and not supported. On some railways the joints are half staggered. Short stagger is on trial on the Indian and British Railways. The influence of rail joints on the wear of rails on curves has not been studied.

Question 21. — *In the case of curves at points and crossings, is the wear of the rails greater than in the case of curves on the open line? For what reasons (absence or reduction of the superelevation and transitions...)?*

The wear of rails laid on the curve at points and crossings is in general greater than on plain track. This is attributed to:

i) absence of transitions;

ii) greater deficiency in superelevation;

iii) heavier impact associated with points and crossings;

iv) difficulty in maintaining points and crossings, particularly fastenings.

Question 22. — *What shape does the wear of the grooved rails in curves take (give drawings of the profiles of worn and non-worn rails)?*

None of the railways use grooved rails on curves.

Question 23. — *Influence of the kind of sleepers (wood, metal, reinforced concrete), the fastenings, and the sleeper spacing.*

The type of sleeper and spacing may have indirect influence on the wear of rails on curves, as certain types of sleepers may keep the track in good alignment and level thereby reducing the incidence of high transversal forces. Metal sleepers offer greater resistance to transverse movement of track and therefore maintain better alignment but on the other hand due to their greater resistance to displacement greater transversal forces are induced, if there happens to be slight irregularity in curvature. Closer spacing helps in maintaining better alignment and level. Sufficient data has not been maintained by the railways to analyse this aspect in detail.

Question 24:

a) *In addition to lateral wear of the head, have you experienced any deformation of the rails, such as turning over owing to the deformation of the web?*

What are the causes of this?

How do you remedy such deformations?

Deformation of the rails such as turning over owing to the deformation of the web has not been normally experienced on the railways. On the American railroads, sometimes rail head turns over somewhat on inner rail of curves due to uneven wear of bearing plates on sleepers. Such deformation has been remedied by using larger bearing plates and keeping the sleepers adzed.

b) *Have you experienced any longitudinal cracks in the web of the rails?*

On what curves.

On the inner or outer line of rails?

On the inside or outside of the track?

At what level?

To what depth?

Longitudinal cracks have been found only on the American railroads on curves

sharper than 3° (1 910 ft. radius) in the inner top fillet of the inside rails almost through the web.

Question 25. — *Influence of defects in the level (repeated low points, loose sleepers)?*

Defects in level, low points and loose sleepers cause heavier rail wear.

Question 26. — *Influence of the climate and atmospheric conditions (close to the sea, in tunnels, wet cuttings, etc.).*

Climatic and atmospheric conditions cause loss of weight of rails due to corrosion, particularly in tunnels, near water troughs and some industrial areas. Rail wear through corrosion is a marked feature in those tunnels used by steam traction. Humid conditions inside the tunnel and water dripping on to the rails also cause corrosion. Influence of sea air is variable but in certain areas in the vicinity of the sea severe corrosion of rails has been observed.

Question 27. — *Influence of the kind of ballast, its profile and the bed.*

Do you modify the profile of the ballast on certain curves in order to increase the lateral strength of the track?

The kind of ballast has generally no influence on rail wear. Deficiency in depth and width of ballast can cause rail wear due to difficulty in maintaining correct level and alignment.

Standard ballast shoulder is increased on the outside of sharp curves on the British Railways in order to increase the lateral strength of the track.

Question 28. — *Various influences*

Nature of formation, drainage, standard of maintenance have also influence on rail wear.

Question 29. — *What are the predominant influences in your opinion?*

Radius of curve, widening of gauge, axle loads and traffic density at different speeds, nature of formation and standard of maintenance are the predominant influences on rail wear on curves.

B. — Features of the rolling stock which may lead to premature wear of the rails.

Question 30. — *Influence of the wheelbase:*

— *of bogies;*

— *of coupled pairs of wheels.*

In general increased side cutting on curves is associated with long fixed wheelbase. On the Central Railway (India) electric freight locomotives, with six wheeled bogies of 15′ 1″ wheelbase, have much more flange wear compared to passenger locomotives with shorter rigid wheelbase. On the other hand, with too short a wheelbase of bogies, the angle of attack becomes greater resulting in increase in side wear.

The effect of coupled axles probably is to cause thrusts at certain points of the track resulting in irregular wear.

Question 31. — *Influence of the effect of out of balance due to the length of the frame and the position of the load.*

The effect of out of balance wheel loads will be to increase the transversal forces on rail resulting in increase in side wear. Also the wear will shift from one rail to the other with the probable result of slightly increasing the total wear. This question has not been studied by the railways in detail.

Question 32. — *Influence of stiffness in the working of the bissels and bogies; devices opposing the rotation of the bogies to damp out their sinusoidal path (the complement to question 10 above regarding motor bogies).*

Stiffness and friction devices of the bissels and bogies will mainly cause increased

wear at the entrance to curves. Spring centering devices cause increased wear over the whole curve but more evenly.

Question 33. — *Influence of play resulting in an increase in the angle of the axle to the rail (or the angle of attack of the axles), especially, taking the maximum wear into account :*

- *the total play of the axle in the track;*
- *the longitudinal play of the axle boxes in the axle guards;*
- *the lateral play of the journals and axle boxes.*

Do you consider it advantageous to decrease or augment certain of these types of play?

In order to reduce the angle of attack of the axles, it is desirable to keep to the minimum the total play of the axle in the track, the longitudinal play of the axle boxes in the axle guards, and the lateral play of the journals and axle boxes, consistent with free inscription of bogies in the track.

The following figures are obtaining on the British Railways :

total play of the axle in the track	— 5/8″
longitudinal play of the axle box in the axle guards for plain bearings	— .10″
for roller bearings . .	— .012″ to .015″
lateral play of journals and axle boxes . . .	— 3/16″

It is not considered advantageous to change the above figures.

Question 34. — *Influence of the tyre profile (attach drawings of profiles without wear and profiles showing the maximum amount of wear allowed).*

Are the flanges of some of the intermediate pairs of wheels reduced or even done away with? Is such a profile satisfactory on with many curves?

Standard tyre profiles of the Indian and British Railways are shown in the accompanying drawings CSL 2126 and T-640 respectively. In drawing No. 2126, thin flange pertains to intermediate and driving wheels, standard flange to leading and trailing coupled wheels and thick flange to carrying wheels of bogies and bissels of locomotives. In drawing No. T-640 type A pertains to leading and trailing coupled wheels and type D to intermediate and driving wheels of locomotives.

Drawings S 809 and S 1983 show the new tyre and minimum profile gauges used on the railways of the London Transport Executive. The condemning tyre profiles of the Indian Railways are shown in Drawing No. CSL 2127.

On the British Railways, the permissible wear is as follows :

Carriage stock (tread wear) :

a) 1/16″ for dining, sleeping, kitchen, post office and buffet cars, and all vehicles running in regular high speed trains;

b) 3/32″ for all other carriage stock.

Wagon stock :

3/16″ wear on tread.

Carriage and wagon stock-wear on tyre flanges.

Minimum flange thickness 7/8″ at 9/16″ from toe of flange.

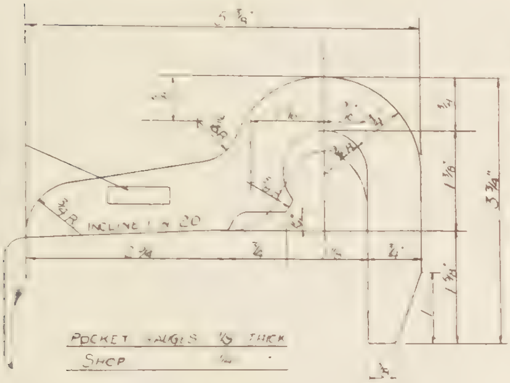
The limits for locomotive stock are under consideration.

On the Indian and British Railways, the flanges of the intermediate wheels are reduced in thickness as seen from the details of standard profiles. On some of the three axled bogies of the South African Railways, the centre wheels are without flanges. This would appear to be satisfactory on sharp curves.

It has been found that with long rigid wheelbase, the flanges of intermediate wheels, even when thinned, foul the track

Note : Wheels to be reported to foreman when worn to this gauge.

Stamp : B/7509
B/573



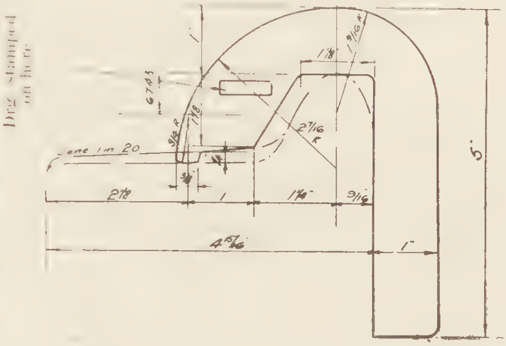
For foremans flange scrapping gauge see Drg. 32661.

Note : Material to be either :

1. Cast steel.
2. Tool steel hardened and tempered.
3. Mild steel case hardened $^1/_{32}''$ deep by « Eternite » process.

London Passenger Transport Board. — Examiners minimum flange gauge. (Drg. No. S-809.)

Note. — Wheels to be reported to foreman when worn to this gauge.
Asset N° B/8788.



Pocket gauges $^1/_8''$ thick.
Shop gauges $^1/_4''$ thick.
Material to be either :

1. Cast steel.
2. Tool steel hardened and tempered.
3. Mild steel case hardened $^1/_{32}''$ deep by « Eternite » Process.

London Passenger Transport Board. — Wheel tread gauge. (Drg. No. S 1983.)

rail, while passing over sharp turnouts with straight switches, and large transversal forces are exerted on the rails. The advantage claimed for the removal of the flange entirely on the intermediate wheels may not however be realised, unless the check rail used on sharp curves is at a lower level than the inner rail. There is also the danger of the flangeless wheel dropping on the inside of the curve unless the flange is made sufficiently wide.

In the case of electric freight locomotives of the Central Railway (India), which have six wheeled bogies, there is no reduction in the flange thickness of the intermediate wheels but the middle axle is allowed 1 1/2″ lateral play.

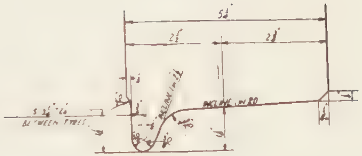
Question 35. — *Influence of the diameter of the wheels.*

Small diameter wheels cause heavier impact and batter at joints particularly through crossing work. The London Transport Executive consider it desirable that all wheel sizes should be such that the ratio of the wheel load in tons, to tread diameter in inches, should not exceed 0.2 for a maximum static loading.

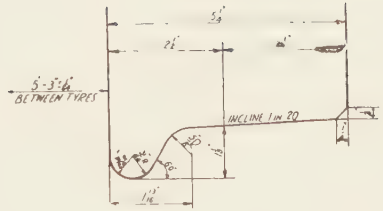
Apart from heavier impact and batter at joints, the smaller wheel induces very high contact stresses which may lead to increased wear.

Question 36. — *Influence of the position of the bogie centre in relation to the axles.*

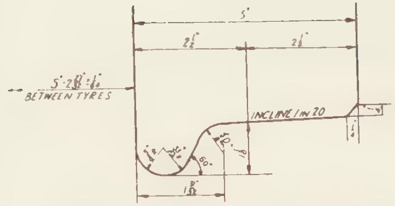
The position of the bogie centre in relation to the axles does not seem to have much influence on the rail wear.



Thin flange-Int. & Drg. wheels.
(Flange clearance on 90 lb. rail-$^{9}/_{16}''$)

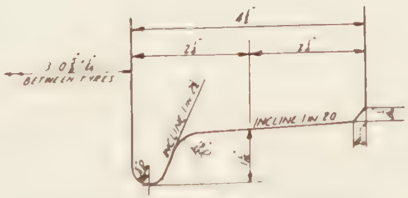


Standard flange-Ldg. & Trg. wheels.
(Flange clearance on 90 lb. rail — $^{9}/_{32}''$)

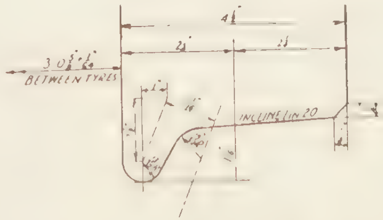


Thick flange-carrying wheels.
(Flange clearance on 90 lb. rail — $^{13}/_{64}''$)

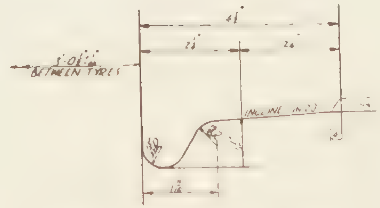
BROAD GAUGE



Thin flange Int. & Drg. wheels
(identical to Drg. No. E/SL 217/198, 199)
(Flange clearance on 50 lb. rail — $^{33}/_{64}''$)



Standard flange-Ldg. & Trg. wheels
(identical to Drg. No. E/SL 217/197)
(Flange clearance on 50 lb. rail — $^{19}/_{[illegible]}''$)

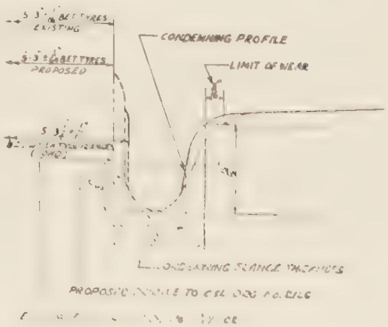


Thick flange carrying wheels.
(Flange clearance on 50 lb. rail — $^{15}/_{64}''$)

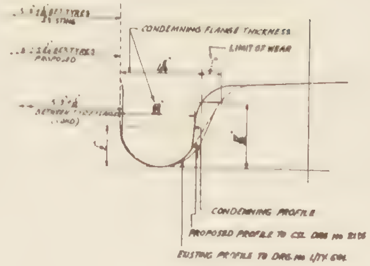
METRE GAUGE

Indian Railways. — B. & MG. — Proposed finished tyre profiles for I.R.S. Locos. — C.S.L. Drg. No. 2126.

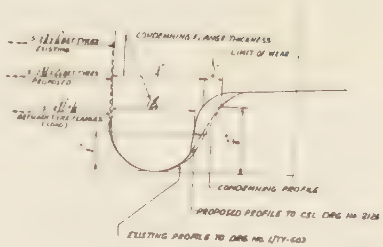
Thin flange, Int. & Drg. wheels.



Standard flange, Ldg. & Trg. wheels

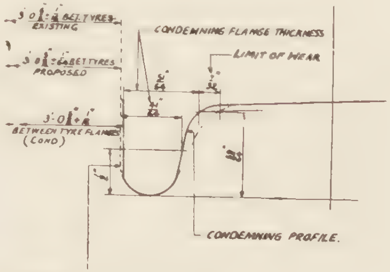


Thick flange, Carrying wheels.



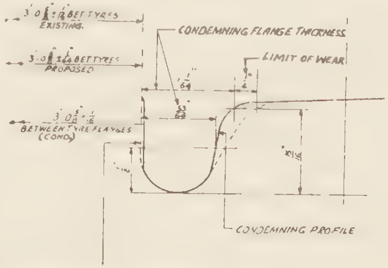
BROAD GAUGE

Thin flange, Int. & Drg. wheels.



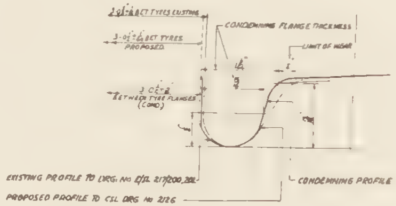
Existing and proposed profile to Drg. No. E SL 217, 198, 199.

Standard flange, Ldg. & Trg. wheels



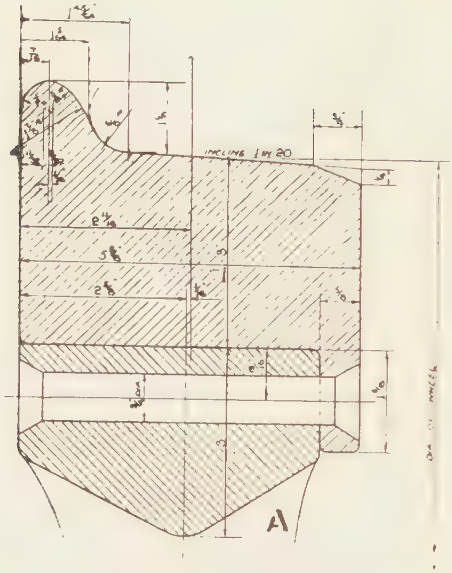
Existing and proposed profile to Drg. No. E,SL 217,197.

Thick flange, Carrying wheels

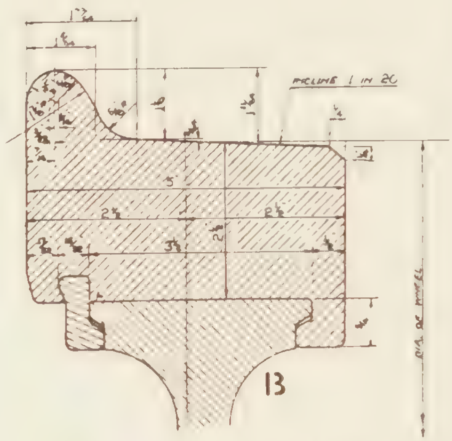


METRE GAUGE

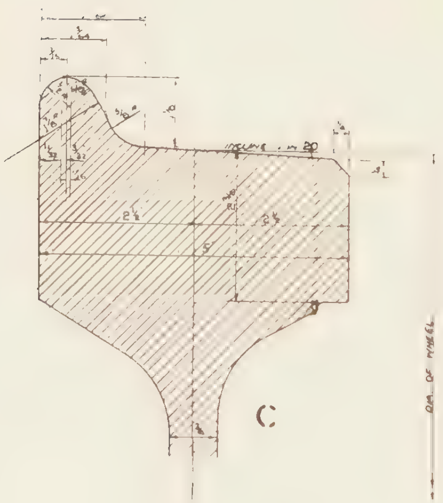
Indian Railways. — B. & Mg. — Proposed condemning tyre profiles for I.R.S. Locos. — C.S.L. Drg. No. 2127.



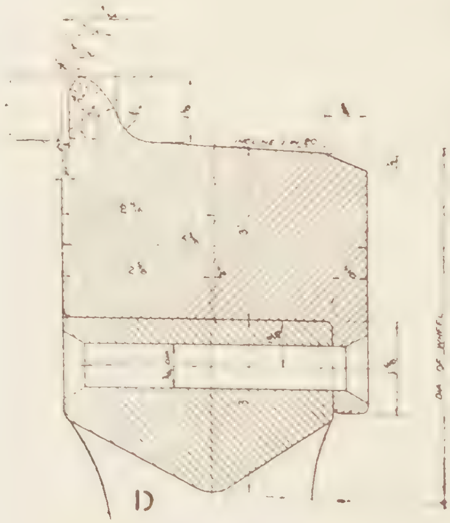
A. — Locomotive thick flange tyre.



B. — Carriage wheel tyre.



C. — 12-ton wagon tyre.



D. — Locomotive thin flange tyre.

British Railways. — Standard tyre profiles. — (Drawing N° T-640).

Question 37. — *Influence of the method of suspension of the motors.*

The South African Railways consider that fully sprung motors are likely to have less severe effect on rails. One of the tube lines of the London Transport Executive was originally operated by locomotives with armature built directly on to the axles. This arrangement was found to result in excessive vibration.

Comparative statistical data are not available to indicate preference to any particular method of suspension.

Question 38. — *Various influences?*

None of the Railway Administrations have offered any comments on this question.

Question 39. — *In your opinion which are the predominant influences?*

The total play of the axle in the track, the longitudinal play of the axle boxes in the axle guards, and the lateral play of the journals and axle boxes, all affect the angle of attack of the wheel on the rail, which has predominant influence on the rail wear.

PART III.

RESULTS OF THE INVESTIGATIONS MADE AND PROPOSED REMEDIES. USE OF RAIL-LUBRICATION PROCESSES.

Results of researches.

Question 40:

a) *What are the qualitative results, and if possible the quantitative of the researches which you have been able to make as regards wear of the rails on curves?*

Very little research work has been done as regards wear of the rails on curves. Rail lubrication has reduced rail renewals but due to the many other variables affecting rail life it is not possible to quantify accurately the saving achieved;

b) *Have any methods been used to determine the position at which contact takes place between the rail and the wheel?*

By measuring the actual stresses in the upper fillet on the two sides of the web and by comparing them with the values obtained in the laboratory under the application of known loads at the various points, attempts have been made to determine the position at which contact takes place between the rail and the wheel.

Question 41. — *What measuring apparatus do you use (direct measurements or recording instruments)?*

The stresses are measured by wire resistance strain gauges and oscillograph equipment. Rail wear is measured by special gauges such as wedge gauges and also by a profile recording device.

The apparatus used on the South African Railways is shown in figures 4 and 5. The scales are calibrated in pounds per yard; for the top wear two scales are provided. One gives the top wear when there is no side wear and the other is calibrated to give average correct total wear readings in conjunction with side wear, which is read on a separate scale. The calibration is based on standard average profiles. For research work a similar gauge has been developed using dial gauges calibrated in millimetres, depth of wear enabling accurate figure to be obtained for the total wear with the aid of conversion graphs or tables.

Question 42. — *In particular what relationships have you been able to establish between the wear of the rails and:*

- *the radius of curve of the track;*
- *the rigid wheelbase of motor vehicles and trailers, the motor and other bogies, the real angle of attack of the different vehicles on curves of various radii;*

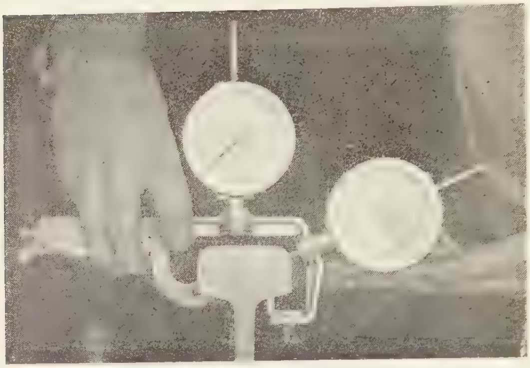


Fig. 4.

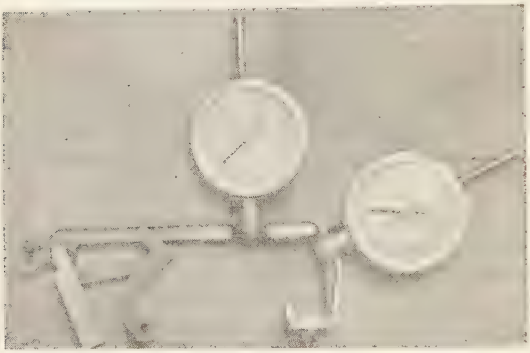


Fig. 5.

— *the axle loads;*
— *the speeds;*
— *the number of pairs of wheels passing or the tonnage of the traffic;*
— *the surface of contact between the rails and the flanges of the wheels;*
— *the stresses in the metal due to the transversal thrust against the rail;*
— *etc.*

The wear increases inversely with the radius of the curve (see plate I). The lateral wear increases with the real angle of attack of the wheels on the rail. The axle loads and speeds have some influence and the wear definitely increases with the tonnage of traffic. Due to very little experimental data being available, no relation has been established between rail wear and the surface of contact between the rails and wheels, the stresses in metal due to the transversal thrust, etc.

Question 43. — *Have you been able to establish either continuity of contact between the tyres of the wheels and the outside rail (or inside rail), or oscillation of the axles between the two lines of rails, according to the radius of curve, the characteristics of the vehicles, and their speeds?*

On curves there is continuity of contact between rail and wheel in most cases. There are, however, variations in the lateral wear along curves, indicating variations in transversal reaction. Specific study of this problem has not been made.

Question 44. — *Does any excess inclination of the running surface appear to you to be due to the tipping of the rail when a train is passing? Have you been able to observe this? measure it? record it?*

Excess inclination of the running surface, due to the tipping of the rail when a train is passing, has not been found. With some cast iron sleepers on the Indian Railways, excess inclination has been observed due to distortion of the tie bars or defective packing, but not due to tipping of the rail.

Question 45. — *Have you carried out researches into modifications in the structure of the metal? What have you found? Will you please send us macrographs and micrographs if available.*

Experiments have been carried out by the American railroads with ordinary carbon rails heat treated and also with alloy steel rails. Heat treated and alloy steel rails are not, however, generally used because of high cost.

Question 46. — *What limits of wear do you allow before withdrawing from service (reduction in the thickness of the*

head, inclination of the chamfered portion, etc.)?

On the British Railways, maximum reduction in thickness of head is 3/8″ (9.5 mm) but this is dependent on axle loads. Side wear on both faces resulting in a reduction of head width of about 23 mm is permitted as on extreme limit. The angle of side wear is 26 degrees.

The limits of wear permitted on the South African Railways are shown in the rail profiles in figure 6. On the railways of the London Transport Executive the minimum rail depth for electric stock is 4 7/8″ and for steam stock 5 1/8″. Side cutting wear is limited in the amount and in the angle of wear as presented by a side-cut wear gauge.

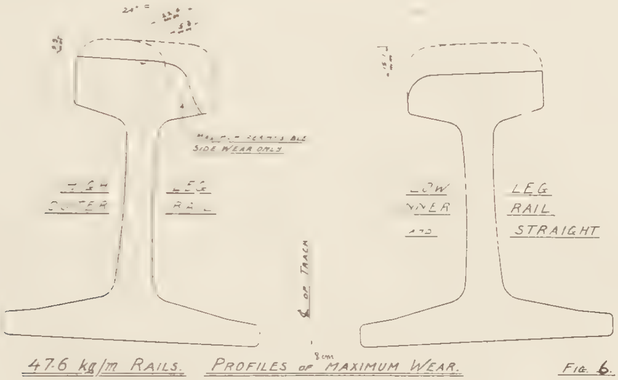


Fig. 6.

On the Central Railway (India), maximum permissible side wear is 3/8″ for 90 lb. R. and 100 lb. B.H. rails and the maximum wear on the running surface is 5/8″. On the American railroads, no definite limits have been laid down.

Question 47 :

a) *Are these limits established in terms of :*

— *the reduction in the strength of the rail (breakages reported);*

— *a tendency of the flange to jump over the head of the outer rail?*

The limits have been established on consideration of the reduction in the strength of the rail, and also the tendency of the flange to climb up the outer rail.

b) *Have these limits been arrived at empirically or according to theoretical studies, details of which please give.*

The limits have been arrived at on the basis of experience.

c) *Have you in particular determined the values of the coefficients of stability, giving the degree of safety against the risk of jumping the rail?*

Experience has shown that the limits laid down give sufficient margin of safety. No tests have been made to determine the values of coefficient of stability.

d) *Have any derailments been due to the flange jumping the rail owing to the chamfering of the head of the rail?*

There has not been any case where the chamfering of the worn head of the rail has been found to be the single initiating cause for derailment due to the flange jumping the rail.

Remedies adopted or proposed, or merely under consideration to reduce the wear of rails on curves.

Question 48. — *Have you attempted to*

modify certain regulations concerning the laying of the track, in particular :

— *the gauge ? Results obtained ?*

— *the superelevation ? Results obtained?*

What devices will you employ to overcome the widening of gauge and the turning over of the rail ?

Gauge widening is carried out on curves to the limits prescribed in table 1. This practice has been adopted to alleviate the thrust on the outer rail and prevent undue side wear. It has been found that unless this is done the passage of traffic, especially 8 wheeled coupled locomotives spread the gauge and thus weaken the hold of the chair or baseplate fastenings. Previously more widening of gauge was allowed but the widening has been reduced in the recent years in order to reduce the oscillations and to obtain steadier running.

The superelevation is provided not for the fastest train but for an intermediate speed which is determined from experience. On the Indian Railways and also the American railroads extra spikes are provided to prevent widening of gauge. On the American railroads eccentric base plates are provided to prevent turning over of the rail.

Question 49. — *Have you studied or tried or are you considering modifications to the profile of the rails or tyres that will give the desired results ?*

On lines with many curves, where the same stock is always used, have you endeavoured to make the profile of the tyres harmonise with that of the rails in order to reduce reciprocal wear ?

New rail sections which are deeper and stronger and in which the metal has been placed to the optimum advantage, have been introduced in the recent years on the American railroads and also on the British Railways. New rail sections designed on similar principles are being rolled for the Indian Railways.

No attempts have been made to harmonise the tyre profiles with that of the rails in order to reduce the reciprocal wear.

Question 50. — *Have you adopted, tried or considered the use of rails made of harder steel, special steels, or heat treated rails ?*

— *chemical composition;*

— *method of treatment;*

— *characteristics (tractive, shock, resilience, Brinell hardness tests, macrography, micrographical examinations, etc.);*

— *radius of the curve above and below which these rails are used;*

— *results of experience of wear (comparison of the reduction of the transversal sections).*

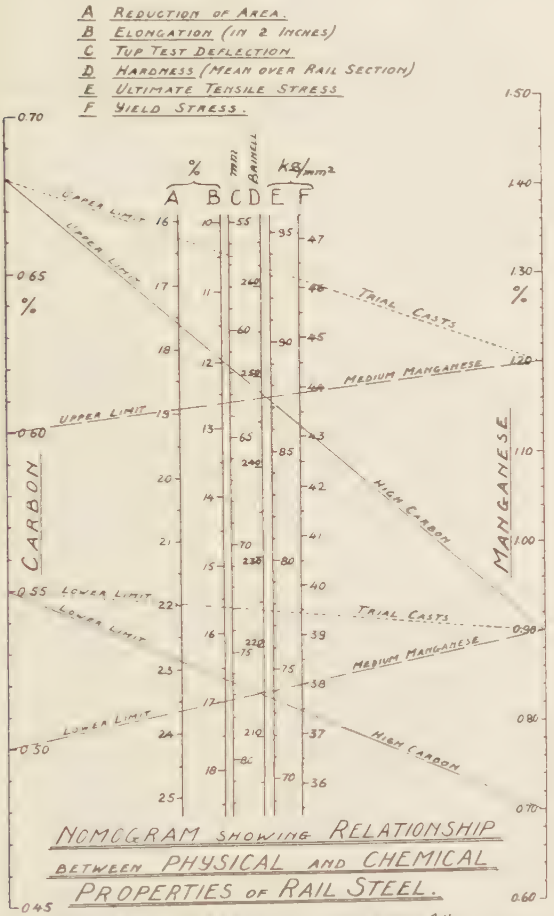
Heat treated and alloy steel rails have been experimented on the American railroads but are not generally used because of high cost. Chrome steels have been tried on the Indian and British Railways but the increased life obtained was not commensurate with their extra cost. With sorbitised rails tried on the British Railways corrugations appeared on the running surface resulting in very noisy running.

From a statistical analysis of the test results of locally produced rails, the South African Railways prepared a nomogram giving the average relationship between the chemical and physical properties which is shown in figure 7. It is expected that for an increase of 1.0 kg/mm² in the tensile strength due to more manganese being added, the life of the rail will be increased by 8 %. Also the ordinary rails are sorted into high and low tensile strength respectively and those of high strength are being used in curves of high wear. Higher manganese rails are also being used on curves and results obtained to date confirm the expectations.

On the Indian Railways, medium manganese rails have been found to be more

wear resisting compared to ordinary carbon rails.

The London Transport Executive tried 14 % manganese rails on curves subject to heavy wear but have found that it is not prudent to turn these rails in order to expose both sides of the rail head to side wear owing to brittleness of the rails.



NOMOGRAM SHOWING RELATIONSHIP BETWEEN PHYSICAL AND CHEMICAL PROPERTIES OF RAIL STEEL.

47.6 kg/m RAILS. (SOUTH AFRICAN RAILWAYS) FIG. 7

Question 51. — *Has the use of rails of this type been limited to points and crossings?*

High manganese rails have been used mostly in points and crossings and their economic value for crossings has been fairly established.

Question 52. — *Do you turn the rails end to end on the outer line of rails? Do you change them over from one line to the other in order to prolong their life? Have such methods given satisfactory results?*

Rails are turned end to end on the British Railways but the other railways do not normally adopt this practice as the rail is already sufficiently weakened to be of use in the same location. The rails are however changed from one line to the other on most of the railways in order to prolong the life. This practice has given satisfactory results.

Question 53. — *Have you laid a check rail along the inner line of rails in order to change the guiding of the axle from the outer to the inner wheels?*

Below what radius of curve (for both standard and metric gauges)?

On the Central Railway (India), check rails are used along the inner rail, on curves sharper than 5° (1 146 ft. radius) on considerations of steep gradients, speeds, etc., in ghat sections, although the rules prescribe 8° (716 ft. radius) and 14° (409 ft. radius) as the limits for Broad (S.G.) and Metre (M.G.) gauges respectively for using the check rails. The railways of the London Transport Executive use check rails as a standard on all curves with radius of 660 ft. or less.

The British Railways use check rails on curves where excessive wear has occurred on the running face. The American railroads use check rails sometimes on curves sharper than 10° (573 ft. radius). On the South African Railways (M.G.) check rails are normally laid on curves sharper than 150 m (492 ft.). The Egyptian Railways use check rails on curves sharper than 500 m (1 640 ft.) radius.

Question 54. — *What widths have been adopted for the flangeways (in terms of the radius and over gauge of the track)?*

The flangeway when laid is adjusted to 65 mm (2.5″) on the South African Railways. On the railways of the London Transport Executive, the flangeway is 1 3/4″ for turnouts (4′ 8 1/2″ gauge), and 2″ for curves (4′ 8 5/8″ gauge). On the British Railways, the flangeway is 1 3/4″ for 4′ 8 1/2″ gauge, and on the American railroads it is 1 7/8″.

On the Indian Railways, the normal flangeway clearance of check rails on curves is 1 3/4″ for Broad gauge (S.G.) and 1 5/8″ for Metre gauge (M.G.). These clearances are, however, increased by half the difference between the gauge to which the curve is actually laid and the corresponding exact gauge.

Question 55. — *Is the check rail carried over the whole length of the transition and over a certain length of the straight section?*

On the British, Indian, and South African Railways, the check rails are laid over the whole curve including the transition and a small length of about 50 ft. on the straight. On the American railroads and the Egyptian Railways the check rail is carried over the entire curve including transitions.

Question 56. — *Have you adopted any special methods of fastening? (Please attach drawings.)*

The method of fastening adopted varies on different railroads in America. On the South African Railways, the check rail and inner rail are carried on a double chair on wooden sleepers; on steel sleepers they have a common centre clip. The British Railways and the London Transport Executive use no special method of fastening. The Central Railway (India) use cast iron chairs for fixing check rails with B.H. track.

Question 57. — *Are check rails used for any other reason than to delay lateral wear of the outside rail (safety, to make the track more rigid, etc.)?*

Check rails are used on curves to reduce lateral wear of the outer rail as well as to increase safety against derailments and to increase the lateral strength of track.

Question 58. — *What are the drawbacks of checkrails (increasing the train resistance, reducing their speed...)?*

The chief drawback of check rails is that they increase wear on the back of wheel flanges and increase track maintenance costs. The train resistance is also slightly increased.

Question 59. — *What results, with figures if possible have you obtained as regards reduced lateral wear of the outer rail from the use of a check rail?*

Definite figures are not available. On sharp curves decided reduction in side cutting of the outer rail has been observed.

Question 60. — *Do you make use of any method of lubricating the inner sides of the heads of the rails such as:*

a) *direct lubrication of the rails:*

by hand brushing;

greasers mounted on trolleys, hand operated;

greasers mounted on motor trucks, hand operated or working automatically.

On the Central Railway (India), rails are lubricated by hand on the electrified suburban sections. On the American railroads this method has been adopted sometimes but generally on most of the railways the rail is lubricated by greasers mounted along the track, working automatically, actuated by wheel passage.

b) *Lubrication of the wheel flanges :*
greasers carried by the motors;
greasers fixed to the rails at the entry to curves.

Please describe the arrangements used and the way they work (with drawings, diagrams or photographs if possible).

Flange oilers are sometimes used on the American railroads. The most common method is however to fix lubricators such « P and M ». « Hurcol » or « Aladdin » type to the rail at the entrance to the curve. These lubricators are operated either by rail deflection or by wheel tread depressing a plunger. The working of these lubricators has not been entirely satisfactory on the Indian Railways.

Check rails on the South African Railways are hand lubricated or from a single rail barrow. On the railways of the London Transport Executive sponge type lubricators are used for lubricating the backs of flanges for passage through check rails. They are also experimenting with a vehicle mounted flange lubricator.

Question 61. — *Below what radius are curves lubricated ?*

There is usually no fixed rule as to the curvature below which lubricators are used. Traffic intensity and speed are to be taken into consideration. Most of the curves of the London Transport Executive are lubricated. On the Central Railway (India) curves sharper than 5° (1 146 ft. radius) and on the American railroads curves sharper than 3° (1 910 ft. radius) are lubricated.

Question 62. — *What are the advantages and drawbacks of the apparatus used, in particular as regards :*

— *the precision of the spraying of the rails (risks of skidding, upsetting the electric circuits, etc.);*

— *their efficacy as regards the circulation of successive pairs of wheels, and throughout the whole curve ?*

Generally the track rail lubricators have been found to be very effective and no serious difficulty has been experienced.

On the Indian Railways, lubrication by mechanical lubricators has been found to be patchy. Early troubles of skidding have mostly been overcome on the South African Railways but some difficulty remains in regard to the constant emission of grease. There are also differences between the lengths of curve lubricated at various locations.

Question 63. — *Can you give the cost of such apparatus (comparison of the different methods) ?*

The cost of the lubricator varies from £ 25 to £ 40. The cost of maintenance and operation depends on the intensity of traffic and no definite figures are available.

Question 64 :

a) *What sort of oil is used ?*

Are special arrangements made during cold or hot weather ?

Graphite grease is used on the Indian and British Railways. Special oil Caltex 904 or Shell 2006 is used both in winter and summer on the South African Railways. The London Transport Executive use light machine oil.

b) *With each method of lubrication, how much oil is used (discharge oil per kilometre of rail lubricated, frequency of the greasing, consumption per kilometre of track effectively lubricated and per pair of wheels passing, etc.) ?*

On the railways of the London Transport Executive, discharge per oil box is about 2 pints per week for about 400-8 car trains per day. Other railways have not maintained any statistics.

c) *What is the annual cost of the oil consumption and maintenance of each apparatus ?*

The annual cost of maintaining and servicing the oil box is £ 6-10-0. Cost of oil is 2 s./3 d. per gallon. The cost of mechanical lubrication on the Central Railway (India) has been found to be about £ 7 per mile per month.

Question 65. — *What results have been obtained by lubrication, especially as regards :*

a) *the track : wear of the rails (importance of the reduction of wear, increased life), saving in sleepers, suppression of grinding, etc.*

Lubrication of rails on curves has been found to be effective in reducing wear and prolonging the life of rails, in some cases almost doubling their life but detailed comparative statistics have not been maintained by the railways.

b) *the tyres of the wheels of traction and trailer stock (increased mileage).*

This is under investigation by the London Transport Executive but no data is at present available.

c) *the consumption of energy (fuel, oil, electric power) and the loads hauled.*

No data is available.

Question 66. — *What is the annual saving obtained by lubrication, per line or for the whole system ?*

Detailed figures are not available and it is not therefore possible to quantify.

Question 67. — *Observations and various suggestions.*

All the aspects of rail wear have been covered in the detailed questionnaire and the Railway Administrations have no observations or suggestions to make.

SUMMARY.

Preliminary data.

The characteristics of track layout vary on the railways due to differences in the nature of terrain, gauge, traffic density, axle loads and speeds. For the same reasons the characteristic features of rolling stock are different on the various railways. The minimum radius obtaining on the British Railways is smaller compared to that on the other standard gauge or Broad gauge railways. Flat-footed or Vignole rails are more in general use.

Rails are usually manufactured of high carbon steel of tensile breaking strength of 70.0 to 86.7 kg/mm² (44.44 t to 55.04 t per sq. inch). The rail steel of the American railroads has a slightly higher carbon content and a tensile breaking strength of 84.0 to 98.0 kg mm² (53.33 t to 62.2 t per sq. inch). The tyre steel has normally a higher breaking strength than that of rails, that of motor bogies being 99.2 to 108.7 kg mm² (63.29 t to 69 t per sq. inch) and of trailer bogies 78.7 to 88.2 kg/mm² (49.96 t to 56 t per sq. inch).

The lateral wear of outer rail is generally more pronounced on curves of less than 2 000 ft. (610 m) radius, but on American railroads the wear is noticeable even on curves of longer radius. The inner edge of outer rail gets chamfered due to side wear but the inside rail table wears off practically parallel to the foot of rail. Based on experience and on consideration of strength, most of the Railway Administrations have laid down maximum limits of wear. The Association of American Railroads have however not found it advisable to specify the limits and it is left to the judgment of the maintenance officers.

PART I.

RUNNING EFFECTS ON RAILWAYS OF LOCOMOTIVES AND RAIL MOTOR COACHES WITH MOTOR BOGIES.

Electric traction has been introduced on the railways at different periods. Motor coaches with motor bogies have been running for nearly 60 years on some of the lines of the London Transport Executive. Motor bogies of motor coaches, with traction motors axle hung and nose suspended,

have generally been found to produce more wear on curves, the articulated double bogie type electric freight locomotive coming next, in the order starting from the worst, and last the electric passenger locomotive with 2-6-4 wheel arrangement and with traction motors frame suspended. The American railroads have not particularly noticed any bad effect of motor-bogies.

Centering devices countering the rotation of motor-bogies are not provided in the case of motor-coaches. Such centering devices are fitted on the electric freight and passenger locomotives. The bogie centre of 4 wheeled bogie is usually in the centre of wheelbase except in some of the latest bogies of the London Transport, it is slightly offset to give more weight on the driving axle. In the case of 6 wheeled bogies, the practice varies on different railways.

The greater wear of rails due to motor-bogies of motor-coaches is attributed to the greater amount of unsprung mass of the axle, low centre of gravity of the vehicle, smaller diameter of the heavily loaded wheels, higher rates of acceleration and deceleration, and unsymmetrical application of torque. Higher axle loads and larger centering forces of bogies may cause greater transversal reactions on rail resulting in more wear.

PART II.

CHARACTERISTICS OF TRACK-LAYING ON CURVES AND DETAILS OF THE ROLLING STOCK LIABLE TO CAUSE PREMATURE WEAR OF THE RAILS.

A. — Laying the track on curves.

The smaller the radius of curve, the greater is the wear of rail in general. There is no definite comparative statistical data to establish a quantitative relationship, between the degree of wear and the radius of curve, but it may be stated, that, the rate of wear, all other conditions being the same, varies inversely as the radius of curve.

Excess or deficiency of cant beyond certain limits, insufficient length of transitions, excessive rate of gain of cant and of deficiency of cant and irregularities in the curvature of track adversely affect the wear of rail on curves. The Railway Administrations have laid down limits for these various factors on considerations of comfort, safety and maintenance. The superelevation of track is calculated to give equilibrium conditions for trains of intermediate speed, ensuring that the deficiency of superelevation for the fastest train is within the permissible limits. The deficiency of cant is reduced at higher speeds on the British Railways, since track imperfections have greater influence at such speeds.

The track gauge is generally widened on sharp curves to alleviate the thrusts on the outer rail and to avoid undue side wear. This widening of gauge is kept to the minimum required consistent with free inscription of bogies in the track, in order to reduce the angle of attack of the wheel on the rail, to reduce the oscillations and to obtain steadier running.

Heavy gradients increase the wear through greater tractive effort or braking necessary and also due to wheels slipping.

Rail joints on curves are normally laid in line (i.e. opposite each other) and they are suspended and not supported. Low joints, loose sleepers, and defects in level set up rolling and oscillations of rolling stock with adverse effect on rail wear. The kind of ballast has little effect on rail wear, provided the ballast section is adequate and proper drainage is ensured. Climatic and atmospheric conditions, proximity to sea and conditions inside the tunnels affect the wear of rails.

The wear of rails on curves at points and crossings is comparatively greater, due to absence of transitions, more deficiency of cant and higher impact at crossings.

B. — Features of the rolling stock which may lead to premature wear of rails.

Longer wheelbase, stiffer centering devices and smaller diameter of wheels have adverse effect on the wear of rail on curves. Also too much of lateral play of the axle in the track, or too short a wheelbase, increases the angle of attack of the wheel on the rail, resulting in increase in lateral wear. The clearances and limits of wear which augment lateral play of axle in the track should be kept to the minimum. Fully sprung motors may have less severe effect on rail wear, but definite comparative data is lacking.

PART III.

RESULTS OF THE INVESTIGATIONS MADE AND PROPOSED REMEDIES. USE OF RAIL LUBRICATION PROCESSES.

Very little research work has been done as regards wear of rail on curves. Rail lubrication has reduced the wear but due to many other variables affecting rail wear, it is not possible to assess accurately the saving achieved. The radius of curve, rigid wheelbase of locomotives and motor-bogies, lateral play of axle in the track and the real angle of attack of wheel on the rail, intensity of traffic and tonnage, axle loads and speeds, surface of contact between rail and wheel flange and stresses in rail are some of the many variables which affect rail wear on curves and it has not been possible to establish a relationship between each of these variables and the degree of wear. The standard of maintenance has a great influence on rail wear and has also to be taken into consideration while making comparisons.

The limits of side wear and table wear which have been established from experience and from considerations of strength have proved satisfactory and there has not been any case where the chamfering of the worn head of outer rail has been found to be the single initiating cause of derailment due to the flange jumping the rail.

Heat-treatment of ordinary rails and use of alloy steel rails have been experimented on the American railroads but not found suitable for general use because of high cost. Chrome steel rails and sorbitized rails have not proved a success. Medium manganese rails have been found to be better wear resisting and they cost very little more than ordinary rails. It would perhaps be advantageous to use medium manganese rails on sharp curves where wear is more pronounced. High manganese steel rails have proved their economic value for crossings.

Rails are not turned end to end except on the British Railways. They are usually changed from main line to secondary or branch line in order to prolong their life.

Check rails are used on sharp curves of radius varying from 1 146 ft. to 573 ft. or less on standard or Broad gauge and on curves of radius varying from 492 ft. to 409 ft. or less on Metre gauge. They are extended over the whole length of curve including transitions and on some railways for a short length of about 50 ft. on the straight. Check rails are used to reduce lateral wear of outer rail, to prevent derailments and to increase the lateral strength of track. The flangeway clearance of check rail is determined taking into consideration the widening of gauge on the curve so that the wear is evenly distributed between the outer rail and the check rail. The main drawback of check rail is that it causes extra wear on the back of wheel flanges and also increases track resistance.

Rails on curves are generally lubricated by greasers or lubricators such as « P & M », « Hurcol », or « Aladdin » fixed to the rail at the entrance to the curve. Wick type lubricators are used on the lines of the London Transport Executive. All these lubricators are operated either by rail deflection or by wheel tread depressing a plunger. The working of some of these lubricators has been found to be patchy and not satisfactory on the Indian Railways where hand lubrication has had to be resorted to.

Flange oilers are sometimes used on the American railroads. On the railways of the London Transport Executive, sponge type lubricators are used for lubricating the backs of flanges for passage through check rails. On the South African Railways, check rails are hand lubricated or from a single rail barrow.

There is no fixed rule as to the curvature below which rails are lubricated, the actual conditions obtaining on a curve and the increase of wear being taken as the criterion. On the American railroads, curves sharper than 3° (1 910 ft. radius) are lubricated.

The cost of a lubricator varies from £ 25 to £ 40, and their cost of operation and maintenance depends on the traffic intensity. On the lines of the London Transport Executive, the discharge per oil box is about 2 pints per week for about 400-8 car trains per day and the cost of oil is 2 s./3 d. per gallon. The annual cost of maintaining and servicing the oil box is £ 6-10-0. On the Central Railway (India), the cost of mechanical lubrication has been found to be about £ 7 per mile per month.

Lubrication of rails on curves has been found to be effective in reducing wear and prolonging the life of rails, in some cases almost doubling their life.

INTERNATIONAL RAILWAY CONGRESS ASSOCIATION

16th. SESSION (LONDON, 1954).

QUESTION 8.

Determination of the principles of geographical and functional organisation of a railway system. Simplification and retrenchment of the administration of railways.

REPORT

(America (North and South), Australi (Commonwealth of), Burma, Ceylon, Denmark, Egypt, Finland, India, Indonesia, Irak, Iran, Republic of Ireland, New Zealand, Norway, Pakistan, South Africa, Sweden and the United Kingdom of Great Britain and Northern Ireland and the territories for whose international relations the United Kingdom is responsible),

by Bengt ADAMSON,

Superintendent, Swedish State Railways.

I. GENERAL ORGANISATION.

A. General view.

Many definitions of the concept « *organisation* » have been given. The following has been proposed by OLIVER SHELDON.

« Organisation is the process of so combining the work which individuals or groups have to perform with the faculties necessary for its execution that the duties, so formed, provide the best channels for the efficient, systematic, positive, and co-ordinated application of the available effort. »

It is one of the most important tasks of the leader of any undertaking to maintain an efficient organisation by means of which the aims of the undertaking may be attained in the best way. This means on the one hand that the most suitable organisational structure should be established and on the other that every post in this organisation should be manned by the right man.

The following *principles of organisation* may be said to be fundamental.

1. The various tasks to be performed shall be established and divided up horizontally in a suitable way among different organs and persons.

2. Responsibility and authority shall be divided up vertically in a suitable way.

3. Efficient coordination must be established and maintained.

4. The organisation shall permit of an efficient control from top to bottom of the undertaking.

5. Every person who has been allotted one or several functions, shall alone be responsible for the execution of the duties belonging hereto.

6. If a person is made responsible for a function or a task he shall also be given the corresponding authority.

7. An essential condition for efficient leadership is that the number of persons directly subordinated under a chief be limited to an adequate number.

The American H. A. HOPF [1] has propounded *the ideal division of authority and functions* in an undertaking in the above chart. HOPF also submits some rules which ought to underlie all efforts to improve organisation. The following may be quoted here :

1. Establish the smallest number of levels of the structure essential to sound operation;

2. Place authority as closely as possible to the point where action originates;

. . . .

4. Avoid overlapping of functions but always bring related work together under one and the same control;

5. Distinguish clearly among the several zones which comprise the organisational structure i.e. Administration, Management and Operation;

. . . .

9. Effect the widest possible application of the principle of separating planning from performance.

HOPF also warns against « the time-honored practice of using committee meetings as a device for sharing responsibility or even on occasion of dodging it altogether ».

LEVEL OF AUTHORITY	TYPE OF RESPONSIBILITY	GENERAL FUNCTION	EVOLUTION OF POLICY	XTERNAL IMPACTS UPON POLICY
STOCKHOLDERS	OWNERSHIP	ULTIMATE CONTROL	PERIODIC REVIEW OF POLICY	
ADMINISTRATION — CHIEF AND ASSOCIATED ADMINISTRATORS	POLICY DETERMINATION	ADMINISTRATIVE CONTROL	ESTABLISHMENT AND DEVELOPMENT OF POLICY	CONSUMERS INDUSTRY
MANAGEMENT — CHIEF AND SUBORDINATE EXECUTIVES	POLICY INTERPRETATION AND APPLICATION	BUSINESS DIRECTION	POLICY RECOMMENDATION THROUGH SYNTHESIS OF EXPERIENCE AND RESEARCH	GENERAL PUBLIC
OPERATION — SUPERVISORS AND EMPLOYEES OF RANK AND FILE	ADHERENCE TO ESTABLISHED POLICY	ROUTINE PERFORMANCE	PRODUCTION AND UPWARD FLOW OF SIGNIFICANT OPERATING DATA	GOVERNMENT

B. Principal types of organisation.

Three principal types of organisation are usually distinguished, viz :

Line organisation (also called Military organisation);

Line and staff organisation;

Functional organisation.

[1] Paper submitted to the Eighth International Management Congress in Stockholm, 1947.

Line organisation.

A simple line organisation is shown in figure 1.

Line organisation is the oldest and simplest of all types of organisation. The highest chief has here delegated authority in certain matters to his next men, who in turn may have delegated authority to subordinated men and so on down to the lowest level of the scale.

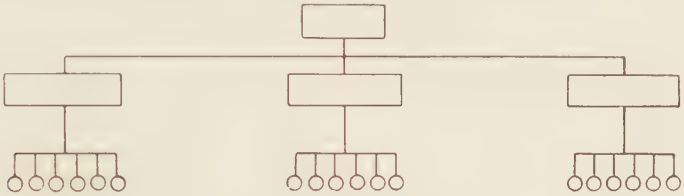


Fig. 1. — Line Organisation.

Line organisation has — as compared with the other types to be described — the advantages of enabling quick decisions and, when necessary, sudden changes of orders. Every chief has absolute, direct authority within his sphere of activity; he alone is responsible to his immediate superior for his duties and every measure decided upon can be carried into effect with a minimum of formalities and loss of time.

As the organisation grows, however, pure line organisation becomes difficult to manage. The higher chiefs must have a very wide knowledge in order to be able to manage everything within their sphere. A chief may be so overburdened with routine work, that he does not get time enough to plan important parts of his work. Over-hasty decisions may be the result.

From the point of view of co-ordination, too, line organisation has disadvantages when the undertaking has exceeded a certain size. There is no guarantee that information coming from subordinated personnel is really passed on up through the various levels of the organisation, or that it will arrive in proper time and in proper order. Perhaps a subordinate chief may take no interest in forwarding certain information that might put him in an unfavourable light. It may also happen, that a chief has not time to listen to what his subordinates have to report.

Line and Staff organisation.

The difficulty, in many large line organisations, of paying sufficient attention to many important questions and their analysis led to specialists being put in as advisors, at first to the highest chief and then also to subordinate chiefs. In this way the line and staff organisation arose.

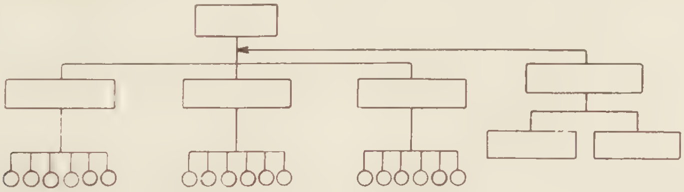


Fig. 2. — Line and Staff Organisation.

In figure 2 is shown a simple type of line and staff organisation.

Line and staff organisation is characterized by the fact that those planning and investigating functions for which specialists are desired have been broken out from the

line organisation. For these functions special advisory or staff departments have been established. In the regular type of line and staff organisation the staff departments only advise the line chiefs or line departments, and all information and orders that the staff departments wish to give the line organisation must be approved by the higher chief, to whom both the staff department and the line chiefs are subordinated.

Nowadays the line and staff organisation exists to a greater or lesser degree within almost all undertakings of any size, for instance in the form of assistants and secretaries to certain chiefs, departments for technical research, for statistics, etc.

The chief disadvantage which may be connected with staff functions is their possible lack of efficiency, as the staff departments have no right of decision. A special danger is the risk of the staff departments failing to get sufficient support from the higher chiefs. Frictions may also arise between staff and line chiefs from their inability always to understand each other's points of view.

Functional organisation.

The third principal type of organisation is the functional type. A simple type of functional organisation is shown in fig. 3.

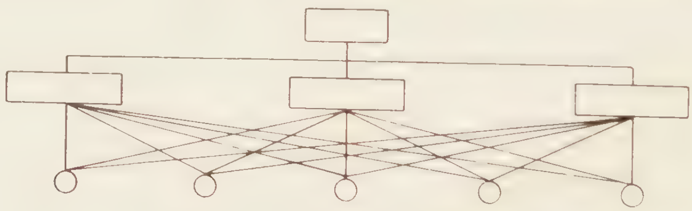


Fig. 3. — Functional Organisation.

Both the line and staff organisation and the functional organisation have developed from the necessity of specializing the duties of different chiefs. Staff and functional chiefs may in different undertakings have responsibility for exactly the same functions, but in the one case they belong to a staff organisation and in the other case to a functional organisation. The difference is to be found in the different relation to the chiefs and departments that are engaged in the immediate operation. In an organisation of staff type the specialists merely advise, in a functional type, on the contrary, a chief with a certain function has decisive power in this function and is wholly responsible for it. If a functional organ has all the implements necessary for the performance of the function it becomes in reality a line organ.

An example of functional control is that exercised by the planning department in a factory, where the foremen of the production department take orders from the planning department and are at the same time subordinated to their immediate chiefs in the line organisation. In addition, such a foreman may have to take orders from other departments, for instance the time-study department, the personnel department, the inspection department, etc.

A characteristic feature of the pure functional organisation is the fact, that a foreman or higher chief has to take orders from more than one superior chief, each responsible for a certain part of his functions.

The functional type of organisation was first described by F. W. TAYLOR in his work « Shop Management ».

The functional type of organisation has been the *subject of considerable criticism.*

Uncombinable with the functional type of organisation is for instance the principle of *unity of command* formulated by the Frenchman H. FAYOL in his work « General and Industrial Management ». It runs as follows : « For any action whatsoever, an employee should receive orders

from one superior only ». FAYOL states the reason for this opinion thus : « As soon as two superiors wield their authority over the same person or department, uneasiness makes itself felt and should the cause persist, the disorder increases, the malady takes on the appearance of an animal organism troubled by a foreign body and the following consequences are to be observed : either the dual command ends in disappearance or elimination of one of the superiors and organic well-being is restored or else the organism continues to wither away. In no case is there adaptation of the social organism to dual command. »

Several *arguments against the functional form of organisation* are stated in a report on « The Maintenance of Direct Authority in the face of Increasing Specialization » prepared by a group of experts under the chairmanship of N. BALIOL SCOTT and submitted to the Eighth International Management Congress in Stockholm 1947. As it also contains much of interest in other respects the summary of this report here might be reproduced.

« The Paper points out that the increased managerial work necessitated by wartime production problems led to the rapid increase of various specialists, such as production controllers, floor inspectors, personnel managers. This proved to be not clear gain, and Production Executives found that their job was not necessarily simplified because these specialists took a hand in it; rather did it seem that they were losing their authority for some part or other of the production activity, while still being operationally responsible. This is because specialization is an organizationally « disruptive force », and the improvement of techniques in these specialized activities ancillary to production has apparently not been matched by corresponding progress in the solving of the resulting task of co-ordination. This is the problem which this paper seeks to examine.

First, an examination is made of the problem of the relationships that arise between Production Executives and the officers of the Production Control, Inspection and Personnel Departments; afterwards general consideration is given to what this analysis discloses. It appears that these specialists are apt to develop a separatist tendency — to « hive-off » as it were from the production staff, and to act as independent authorities. This results in lack of co-ordination and consequent friction between them. The essence of the problem is the delimitation of the exact « content » of each specialist's job.

A warning is issued against so-called « functional » organization (according to which each individual should exercise the separate authority of his own expertise « in respect of his particular function ») when this results in a foreman receiving instructions from a number of supervisors each directing his actions from some specialist angle.

It is pointed out that while each activity is in some measure essential to the business, they vary greatly in importance and in their mutual relationship; some are vital, others not so. Specialists are really performing a « Service » to Production Executives who are responsible for « operations ».

It is suggested that in order to obtain the full benefits of specialization, while minimizing the frictions which frequently follow the creation of any specialist department, General Management should :

1. Construct the organization so as to emphasize the importance of its vital functions, i.e. the Operating Departments concerned with Production.

2. Define duties of Service Departments and their place in the organization structure so as to reflect the ancillary nature of their relationship to the Operating Departments.

3. Ensure that the executives of Operating Departments retain the authority and responsibility for co-ordination, for linking together what has been separated.

Certain further guiding rules are listed which should facilitate the smooth working

relationship between the Production Executives and the officers of specialist Service Departments. Finally, it is suggested that the exact formulation of this relationship is itself of little use unless General Management ensures that all concerned acquire a mutual understanding and appreciation of its nature. »

The inconveniences of the original, strictly functional type of organisation have caused that functional connections nowadays often are arranged in the following way. Only one order line to each unit is found but guidance in certain matters is given by special organs or officers. If in a certain matter this guidance cannot be followed, the matter must be submitted to the superior echelon in the line organisation.

Above different methods of arranging the connections between different organisational units have been described. As regards the delimitation of different organisational units from each other there are also different methods found among which division according to functions and division according to products may be mentioned. A delimitation according to functions is often called « functional organisation ». It is foremost in this sense the writer has taken the term « functional organisation » in this report.

To a certain degree a delimitation of different organisational units according to products can also be found in railway undertakings viz. as regards ancillary services. As regards the real railway service, which may be the chief matter of this report, however, it may be said that the division is made according to functions.

II. ORGANISATION OF RAILWAYS.

A. General.

The *principles of organisation* and the general views on the organisation of an undertaking of any branch, as stated in chapter I, are doubtless *also applicable to a railway system.* However, in view of the variety of activities in a modern railway system, its extent and its geographically wide-spread establishments, as well as the great demands for adaptability to varying traffic conditions, the organisation of railways involves many special problems and difficulties. Their character of common, social undertakings — a character that is manifest whether they are managed privately or by the State — is also a complicating element.

The development of railway organisation has followed different lines in different countries, and to-day there are no two railways having exactly the same organisation.

This report is based on *answers from the following railways :*

Atchison, Topeka and Santa Fe Railway System (U.S.A.);
Atlantic Coast Line Railroad Company (U.S.A.);
British Railways;
Danish State Railways;
East African Railways and Harbours;
Egyptian State Railways;
Finnish State Railways;
Indonesian State Railways;
London Transport;
New York Central System (U.S.A.);
Norwegian State Railways;
Pennsylvania Railroad Company (U.S.A.);
Rhodesia Railways;
Southern Railway System (U.S.A.);
Swedish State Railways.

As every railway always aims at improving its organisation, the organisation dealt with in the answers and in the report may have been changed before the date of the IRCA meeting in 1954. The British Railways have specially emphasized that the Transport Bill — before Parliament at the time when the answer was given — may result in material changes in the organisation of British Railways.

Of course different railways have stressed different questions in their answers. Thus the subject-matter of certain questions has not been quite clearly elucidated in all answers, which explains certain gaps in the

report. The report nevertheless aims at elucidating the subjects in as many aspects as possible, even though in some cases the answers are few or summary.

B. Division of authority and responsibility (Vertical division).

1. Levels of authority.

In the chart reproduced on page 574 2, HOPF distinguishes between four different levels of authority, viz :

Stockholders;

Administration;

Management;

Operation.

This division is made with reference to industrial undertakings in general. If the corresponding division of the levels of authority in a railway undertaking is to be carried out, it may — considering that many railways are State-owned — be suitable to change the word «stockholders » to « owners ». In view of the special sense of the word « operation » in railway terminology, it may also be desirable to change this word to « performance ». Thus the levels of authority in a railway and the general functions connected with them might be said to be :

Level of authority	Type of responsibility	General function
Owners	Ownership	Ultimate control
Administration	Policy determination	Administrative control
Management	Policy interpretation and application	Business direction
Performance	Adherence to established policy	Routine performance

This division will in the sequel be the basis for an investigation of the way in which different railways have arranged for the execution of the above-mentioned general functions and the way the different organs representing the above-mentioned levels of authority are composed.

First, however, it must be emphasized that of course the purport of the above-mentioned general functions is not always the same. Different railways have used many other terms and in a somewhat different sense. As far as possible, however, the writer has tried to eliminate such differences and put the answers under such headings, that they will correspond as closely as possible to the conditions generally obtaining.

2. Ownership-Ultimate control.

For the execution of the ultimate control the following seem to be the current methods :

In privately owned railways :

1. The ultimate control is exercised by a Board of Directors elected by the stockholders.

In State-owned railways :

The ultime control is exercised by the State with one of the following methods or a combination of two or more of them.

2. The control is exercised directly by a ministerial department (or a corresponding body).

3. The control is exercised by a ministerial department (or a corresponding body). Besides the ministerial department there is a consultative committee.

4. The control is exercised by special auditors nominated by the government.

5. A special commission is set up to exercise the control.

Hereafter is a summary of the modes of ultimate control in different railways.

Railway	*Method according to classification above*	*Notes*
Atchison, Topeka and Santa Fe	1	15 Members
Atlantic Coast Line.	1	
British Railways and London Transport	5	British Transport Commission
East African Railways and Harbours	3	The assets are vested in a Commissioner for Transport appointed by the East Africa High Commission. To advise the Commissioner for Transport in the performance of his functions and duties there is a Transport Advisory Council, consisting partly of representatives of the East African Goverments and partly of representatives of commerce and industry, who would also represent the interests of the transport users generally. No representatives of the staff sit on the Council. The Commissioner for Transport is ex officio Chairman of the Council, which consists of nine members : — 3 appointed by the East Africa High Commission. 2 appointed by the Governor of Kenya. 2 appointed by the Governor of Tanganyika. 2 appointed by the Governor of Uganda. The General Manager attends and may speak at meetings of Transport Advisory Council but has no right to vote. There are two sub-committees of the Transport Advisory Council, one to deal with Railway matters and one to deal with Harbour matters. It is the practice for cases concerning Railway or Harbour matters, particularly those involving expenditure on new works or services, to be submitted first to the appropriate sub-committee and then to be referred to the full Council for consideration or to be reported to Council for covering recommendation according to the amount of expenditure involved.

Railway	*Method according to classification above*	*Notes*
Egyptian State Railways. . . .	5	Railway Board composed of : Minister of Communications, — President Minister of Finance Minister of War & Marine Minister of Public Works Minister of Commerce & Industry The General Manager, State Railways Deputy of the Council of Law Under Secretary of State, Ministry of Finance Under Secretary of State, Ministry of Communications — Members
Indonesian State Railways. . .	2 and 4	Incidental checking by Government accountants is prescribed.
New York Central	1	
Norwegian State Railways. . .	2	
Pennsylvania Railroad.	1	The number of members is decided by the Board but must not be fewer than three.
Rhodesia Railways	5	Rhodesia Railways Higher Authority composed of : The Prime Minister of Southern Rhodesia. The Governor of Northern Rhodesia. The High Commissioner for Basutoland, Bechuanaland Protectorate and Swaziland. Such other Minister of the Crown in Southern Rhodesia as the Governor may from time to time appoint.
Southern Railway System . . .	1	
Swedish State Railways	4 (1) and 3 (2)	(1) 3 General Auditors are nominated every year. (2) Railway Council, consisting of 25 members. The chairman and 2 members are nominated by the Government. The other members are nominated by different organisations in trade and industry. The Railway Council is consulted and meets only seldom. Its main function is to form a consultative organ in rate question. A special sub-committee is nominated consisting of chairman and 6 members.

3. Determination of policy. — Administrative control.

According to HOPF, the second level of authority is the administration. The general function of this level is to exercise administrative control and to be responsible for the determination of policy.

To the extent to which the determination of railway policy falls outside the ultimate control it seems possible to arrange the policy according to the following methods :

1. The highest executive head and certain heads of the central departments form the organ by which policy is laid down. Within this organ :

a) the sole decision rests with the highest executive head in most questions ([1]);

b) the decisions are arrived at by means of voting.

2. The highest executive head, certain heads of the central departments and representatives of State and public (sometimes also staff) form the organ by which policy is laid down. Within this organ :

a) the sole decision rests with the highest executive head in most questions ([1]);

b) the decisions are arrived at by means of voting.

3. The highest executive head and representatives of State and public (sometimes also staff) form the organ by which policy is laid down. Within this organ :

a) the sole decision rests with the highest executive head in most questions;

b) the decisions are arrived at by means of voting.

4. A special committee is appointed. Decisions are arrived at by means of voting.

Below is given a summary showing which of the above-mentioned methods are used by certain railways and the way in which the respective organs are composed.

Railway	*Method according to classification above*	*Number of members (including chief or chairman)*	*Composition*
1	2	3	4
Atchison, Topeka and Santa Fe	4	At most 8	Executive Committee. The president is ex officio a member. The other members are chosen by the affirmative votes of a majority of all the directors in office. The chairman is appointed from the members in the same way. Of course, certain matters of policy are also determined by the president, assisted by the chiefs of the central departments.
Atlantic Coast Line. .	1 *a*	6	General Management composed of : President assisted by : Vice-Presidents Operations Law Accounting Traffic Treasurer

([1]) This often means that the highest executive head comes to a decision only after having conferred with that member (or those members) to whose sphere a question belongs.

Railway	*Method according to classification above*	*Number of members (including chief or chairman)*	*Composition*
1	2	3	4
British Railways	2 *b*	9	Railway Executive, consisting of seven full-time functional members (including a chairman) and two part-time members, appointed by the Minister of Transport. *Note* : The British Transport Commission is primarily responsible for policy.
Danish State Railways	1 *a*	7	General Manager and six Chiefs of Central Departments.
East African Railways and Harbours	1 *a*	8	General Manager and seven Heads of Departments. Matters of general policy, however, are the duty of the Commissioner and the Council (see page 508/8).
Egyptian State Railways	1 *a*	8	General Manager, Secretary General, five Heads of Central Departments, Auditor.
Finnish State Railways	1 *a*	10	General Manager, Chief Manager and eight Chiefs of Departments.
Indonesian State Railways	1 *a*	7	General Manager and six Chiefs of Departments.
London Transport . . .	2 *b*	6-8	Railway Executive, consisting of five full-time members including a chairman and a number of part-time members (normally three, at present one) appointed by the Minister of Transport after consultation with the British Transport Commission. The chairman and members shall be selected « from among persons, who appear to the Minister to have had wide experience and shown capacity in transport, industrial, commercial or financial matters, in administration or in the organisation of workers ».
New York Central . . .	1 *a*	—	The Central Departments execute broad matters of policy in the field of operations, maintenance of way and structures and equipment. The Heads of the Central Departments report to the President, who is the Chief Executive Officer, responsible to the Board of Directors.

Railway	*Method according to classification above*	*Number of members (including chief or chairman)*	*Composition*
1	2	3	4
Norwegian State Railways	3 *a*	8	General Manager, three members nominated by the National Parliament, two by the King and two elected by the staff.
Pennsylvania Railroad .	1 *a*	10	Under the Board of Directors, the President, assisted by the Heads of the Departments, determines the policy.
Rhodesia Railways . . .	4	5	Rhodesia Railways Board which shall consist of not more than six nor fewer than five members, who shall be appointed by the Higher Authority. At present the Board consists of : 1. Chairman 2. Member of Northern Rhodesia Government 3. Member of Southern Rhodesia Govermnent 4. Member of the Commercial community 5. The retired Secretary of the Railway Workers' Union. Determination of policy at the highest level is the duty of the Rhodesia Railways Higher Authority (see page 581 9.)
Southern Railway System	1 *a*	6	President Vice-Presidents Operations Law Traffic Finance Comptroller
Swedish State Railways	2 *a*	16	General Manager, 13 Chiefs of Central Departments and two members appointed by the Government, and to be called in by the General Manager in certain cases. Most decisions, however, are made by the General Manager, after consultation only with the Chiefs of the Departments immediately concerned, and very few questions require the presence of all. (Matters of policy are also *discussed* at frequent meetings between the General Manager, the 7 Chief District Officers and the Chiefs of the Central Departments, immediately concerned.)

As to the *powers of the different organs* indicated above, it may be of special interest to see the powers of these organs in some State-owned railways. In order to exemplify this, some extracts from the answers received are given below :

East African Railways and Harbours write as follows :

« The General Manager has power to operate sanctioned working or works expenditure on the Railways and Harbours and to use savings under one head of expenditure to meet excesses on another, subject to the gross sanctioned expenditure not being exceeded.

He may sanction expenditure on any new work or service up to £ 2 500 and create new posts (other than posts of senior officer status — District and Assistant Districts Officers upwards) carrying salaries of £ 900 per annum or below. He also has powers of appointment, promotion, dismissal, etc., in respect of staff in this category. »

« The Commissioner for Transport is required to consult the Council on all matters of general policy and in particular :—

a) any substantial alteration in the tariff of rates, fares and other charges of the Administration;

b) all estimates of revenue and expenditure including loan services;

c) all proposed legislation relating to the Administration prior to its introduction into the Central Legislative Assembly (the legislative body of the East Africa High Commission) or the Legislation Council of any of the Territories;

d) the expenditure of any sum exceeding £ 2 500 in respect of any separate work or service other than a work or service covered by sanctioned working estimates or carried out under an authorised construction betterment or renewals programme;

e) any major alteration in the scales of salaries, wages, hours of employment or other important conditions of employment;

f) any substantial reduction of staff;

g) any substantial change in the organisation of the Administration. »

Indonesian State Railways make the following statement :

« The powers of the G. M. have their limitation in the powers of the central Government Administration with regard to the budget, the railway-tariffs, the time-tables, the salaries and wages, the appointment of higher grade officials and so on.

Owing to these limitations, the G. M. has only competence with regard to :

the personnel, to appoint, to promote and to discharge the lower and middle grade personnel;

the budget, to execute budget measures within the frame as approved by Parliament (naturally the design of the Railway-budget is drafted by the G. M.);

the tariffs, general tariffs and on the whole all rate increases need the approval of the Minister of Communications and the Economic and Finance Council of Ministers, as these tariffs can influence the price stabilization policy of the cabinet.

The G. M. is allowed to introduce special tariffs and tariff-reductions within certain limits;

the time-tables, to fix modifications of minor importance. The other modifications need the Minister's approval. »

London Transport communicates the following :

« The Executive have full power over the Administration of the undertaking except in respect of certain matters such as capital investment, the fixing of fares and charges, sale of property, etc., which must be referred to the Commission. In addition to fortnightly meetings of the whole Executive the Full-time Members hold regular conferences; apart from this the only formal meeting of a sub-committee of Executive Members is the Contracts and Supplies Committee. »

Swedish State Railways write as follows :

« The General Manager has decisive power in all matters with the exception of :

1) disciplinary measures;

2) matters which are reserved for the Government.

Matters of the last-mentioned kind are principally :

division into districts;

basic regulations concerning the relations between the railways and the public;

fares, rates and charges (with the exception of reductions);

general regulations concerning wages and retirement,

appointment of certain higher officials;

number of permanent staff;

estimates for buildings and establishments, for greater reconstructions and extensions, and for new rolling stock;

budget. »

4. **Business direction.**

Although the two terms « policy determination » and « business direction » may be said to be distinct there are great difficulties in defining the limits between them.

The difference between « policy determination » and « business direction » is of the same character as that between « what » and « how ». Just as « what » may often imply a judgement of « how », so the determination of policy must consider the practical possibilities of its application, although this implied judgement is not necessarily stated.

The determination of policy is a central function exercised with reference to the observations made both centrally and regionally.

Business direction embraces the interpretation and application of the policy laid down. These functions are not only central but in most railways also regional. Only rather small railways form exceptions.

The guiding ideas for the policy must be formed and announced by the central organ. This organ must also see to it that the policy is followed and that the desired results are obtained.

Regionally, the policy must be interpreted and brought into effect. The regional organs must also see that the policy is followed and that the desired results are obtained.

In this connection it seems appropriate to mention the tendency in many organisations, not only railways, to let the determination of policy and the necessary central functions referring to business direction grow, until they include a wider and wider competence, a host of detailed instructions and directions of all kinds. If given only in a consultative capacity or for the purpose of further discussions this may, in the author's opinion, be all very well; but otherwise this tendency will have a weakening effect upon regional responsibility and the will to action.

The *central functions* in regard to business direction are exercised by central departments (offices, bureaus). Such are to be found in every railway, but the division of functions varies in a way which will be dealt with in section C.

As to the position and powers of the chiefs of the central departments, it seems possible to discern two main cases.

1. These departments act as staff departments to the executive chief or committee. In this case *orders* are issued by the executive chief or committee. Interpretations, information and inquiries may, however, be dispatched directly. In certain defined matters power may also have been delegated to heads of departments to act on behalf of the executive chief or committee or in their own name. The heads of departments may have a lower rank than the highest regional chiefs.

2. These departments (or some of them) are intermediate organs between the highest executive chief or committee and the regional organs. The heads of departments have definite powers and within these powers orders are issued in their own names. Where this way of working is practised the heads of departments ought to

have a higher rank than the highest regional chiefs.

The mode of working according to *point 1* above is practised by the

Indonesian State Railways;
Norwegian State Railways;
Rhodesia Railways;
Swedish State Railways.

The mode of working according to *point 2* above is practised by the

American railways mentioned in this report;
British Railways;
East African Railways and Harbours;
Finnish State Railways.

The available material gives no possibility of a thorough examination of the differences between these two ways of working. However, it might be presumed that the difference is smaller than one may at first be inclined to think.

Generally the heads of departments may have less powers where the mode of working according to point 1 is practised, but the more powers are delegated to the heads of departments, the more will this mode of working coincide with that according to point 2.

As already said the heads of departments in an organisation according to point 1 can have a lower rank than the highest regional chiefs. According to the author's opinion it is, however, a complicating circumstance if this is the case, and especially if considerable powers have been delegated to the heads of departments. A great personal tact is required especially in matters, which from the regional point of view are not regarded as pure routine matters.

As a matter of fact the organisation according to point 1 has some of the features of a line and staff organisation and the one according to point 2 some of the features of a functional organisation. As will be shown later, the further construction of the organisation at lower levels is very seldom such that the organisation as a whole may be called a line and staff or a functional organisation. In an organisation where the upper part is of the line and staff type certain functional connections are often found, with reference to special functions. In an organisation where the upper part is of the functional type the functions are often separated at lower levels and here organised according to the line and staff type.

The *regional functions* with reference to business direction are exercised by higher regional officers of various rank, often assisted by staff officers or staff departments.

The material in hand affords no possibility of comparing the degree of powers at different levels in different railways.

5. **Performance.**

The dividing-line between business direction and performance is still more difficult to draw than that between the other general functions.

Under performance is to be classed not only the actual work, but also its immediate conduct and supervision. Thus performance is not necessarily a local function, but also to a certain degree a regional one.

As to certain functions, their exercise may also be centrally located. This has reference especially to functions outside of « operation », which it may sometimes be desirable to locate centrally in order that they should be performed with the most efficient output and the smallest possible number of staff.

In the questionnaire no information was requested as regards responsibility and powers concerning the performance, as a report on this would not have fallen within the bounds of this report.

C. Functional organisation (Horizontal division).

1. **General.**

Note :

Certain words used as comprehensive terms for several functions, have a sense substantially different in English and in American terminology. As an instance of words with such a different sense the terms « operation » and « traffic » may be mentioned. In appen-

Chart 1. Groupin

Railway	*Atlantic Coast Line*	*Norwegian State Railways*	*Danish State Railways*	*Finnish State Railways*	*Southern Railway Syst*
Headquarter functions are divided into the following groups	1. Operation [2]	1. Operation	1. Traffic, except *a*) Fares, rates and charges *b*) Motive Power	1. Traffic, except *a*) Fares, rates and charges *b*) Motive Power Road Transport Military matters	1. Operation
	2. Traffic [2]	2. Commercial	2. Fares, rates and charges Accounts Statistics	2. Fares, rates and charges Income audit Statistics	2. Traffic [2]
		3. Civil Engineering	3. Civil Engineering	3. Civil Engineering 4. Railway Construction	
		4. Rolling Stock 5. Electrification	4. Rolling Stock including Motive Power	5. Mechanical Engineering Motive Power Workshops	
		6. Stores	5. Purchases	6. Purchases and Stores	
	3. Finance 4. Accounting	7. Economy		7. Economy Accountancy Personnel Printing	3. Finance Purchases 4. Accountin
		8. Administration	6. Personnel	8. Administration Legal	
	5. Legal				5. Legal
Total number of employees 1951	19 500	25 300	27 000	37 200	40 000

(1) Joint responsibility

(2) The word is used in the American sense (see appendix I)

(3) As to certain operational matters, entrusted to other central departments, in co-operation with those departr

t African Railways Harbours	*Swedish State Railways*	*Indonesian State Railways*	*New York Central*	*Pennsylvania Railroad Company*	*British Railways (Railway Executive)*
peration ommercial ivil Engin-ering Iechanical ngineering cluding orkshops nd locomo-ve running urchases and ores ccounts and ternal audit ort operat-g and admi-stration	1. Operation (2) (3) (including personnel in co-operation with 10) 2. Passenger and Freight Transportation Trains schedules Distribution of passenger and freight stock 3. Traffic (2) 4. Civil Engineering 5. Electrical, Signal and Telecommunications Engineering 6. Mechanical Engineering 7. Workshops 8. Purchases and Stores 9. Finance Accountancy Statistics Basic principles for fares and rates Transport policy 10. Personnel (in co-operation with 1) and General Administration 11. Legal 12. Military and Civil Defence 13. Station auditing 14. Paper and Printing 15. Road Motor Operation	1. Operation Commercial Economic Research Statistics Checking of traffic income 2. Civil Engineering Signal and Telecommunications Engineering 3. Mechanical Engineering Time-tables Workshops 4. Purchases and Stores 5. Finance Certain personnel matters 6. Secretary Certain personnel matters Legal	1. Operation (2) and maintenance 2. Freight traffic (2) 3. Passenger traffic (2) 4. Engineering 5. Purchases and Stores 6. Finance 7. Staff 8. Secretary 9. Legal 10. Public Relations	1. Operation (2) 2. Traffic (2) 3. Purchases, Stores and Insurance 4. Finance 5. Real Estate 6. Audit 7. Secretary 8. Legal 9. Public Relations	1. Operation Motive Power (1) Marine Docks 2. Commercial. Passenger and Freight. Terminals and Cartage. Charges Schemes. Traffic Integration 3. Civil Engineering Architecture Signal and Telecommunications Engineering 4. Locomotive Engineering Motive Power (1) Carriage and Wagon Engineering Electrical Engineering Road Motor Engineering 5. Stores Paper and Printing Estate and Rating Police Civil Defence Fire Protection 6. Staff and Establishment Welfare Medical 7. Public Relations Publicity Research
6 700	65 800	74 000	109 000	137 600	599 800

dix I an attempt has been made to make certain such differences clear. In the sequel English terminology will be used unless otherwise stated.

In all organisations it is attempted to combine adjacent functions in an appropriate way. The way of combining different functions varies, however, in different railways. The way in which these combinations have been made, on the one hand with reference to the Headquarters, on the other hand with reference to regional organs, will be shown below.

2. **Grouping of functions within Headquarters.**

In chart 1 is shown a summary of the grouping of functions within the Headquarters of certain railways. The statements refer to the division of functions among the chiefs responsible next under the highest executive chief or committee. Where the heads of the central departments are also members of an executive committee, the summary states the division of functions among the different members.

From the summary may be gathered, among other things, the following points, which are perhaps worth special mention :

1. Headquarter functions are brought together in such a number of groups that the number of chiefs directly subordinated under the highest executive chief or committee is usually 5-10.

The *Swedish State Railways* has the strikingly large number of 15 groups. This far-reaching division of functions immediately under the highest executive chief has the *disadvantage* that a great burden is devolving upon the General Manager to have to deal directly with so many persons and the risk that policy unity in action will be weakened if the need for co-operation between the departments should not be deeply met by those concerned. The *advantage* is that the need of higher, coordinating chiefs becomes smaller. In practice the 15 groups can momentarily be said to be working in 3 working units, headed by respectively the General Manager, the Assistant General Manager (who is also Chief of the Operating Department) and the Director of Economy.

2. In the American railways : Atlantic Coast Line, Southern Railway System and Pennsylvania Railroad Company, the engineering functions are represented by the man who is responsible for Operation. In the New York Central System, Civil Engineering and Mechanical Engineering are grouped together. In all corresponding non-American Railways, the engineering functions are separated from Operation and divided into at least two groups (usually Civil Engineering and Mechanical Engineering); in certain cases into still more groups.

3. **Grouping of functions within regional organs.**

A detailed statement of the grouping of functions within regional organs in different railways cannot be given within the limits of this report. The report must be restricted to some fundamental differences concerning main functions.

As to the *border-lines at lower regional levels between Operation and Commercial*, mainly the different combinations given may be found on the following table.

The combinations 1 and 2 involve the advantage of a greater specialization, but also a poorer co-ordination than that afforded by combination 3. Combination 2 seems, as compared with combination 1, to offer better possibilities for joint use of staff at the local level, but it also calls for a more all-round training of the staff. In combination 2 special stress seems to be laid upon sales promotion, but there might be a certain risk of the collaboration with the local organs becoming inferior to that according to combination 1.

The answers received show that the different combinations are applied as follows.

Combination 1 : British Railways.

Combination 2 : American railways. mentioned in this report ([1]).

([1]) Claims are sometimes referred to Operation or to Legal matters.

<table>
<tr><th>Functions</th><th>Combination 1</th><th>Combination 2</th><th>Combination 3</th></tr>
<tr><td>Fares, rates and charges. Sales promotion</td><td rowspan="5">Commercial</td><td rowspan="3">Commercial</td><td rowspan="9">All functions combined</td></tr>
<tr><td>Private sidings, warehouse accommodation</td></tr>
<tr><td>Claims</td></tr>
<tr><td>Goods depots</td><td rowspan="6">Operation</td></tr>
<tr><td>Booking offices, parcels offices, reservation offices and other duties outside the duties of platform staff</td></tr>
<tr><td>Train movement</td><td rowspan="4">Operation</td></tr>
<tr><td>Shunting and other external operation at stations, yards and goods depots</td></tr>
<tr><td>Provision of coaching stock</td></tr>
<tr><td>Distribution of freight stock</td></tr>
</table>

Combination 3 : Danish State Railways;
East African Railways and Harbours;
Egyptian State Railways;
Finnish State Railways;
Indonesian State Railways;
Swedish State Railways.

As to the *border-lines at lower regional levels between Operation and Motive Power*, the following two combinations are to be found :

1. The functions Provision and Manning of locomotives are ranged under Operation. Maintenance of locomotives, on the other hand, is ranged under Mechanical Engineering;

2. The functions Provision and Manning of locomotives are ranged under Mechanical Engineering, as is also the Maintenance of locomotives.

Combination 1 has the advantage that all functions concerning the actual movement of trains are taken together.

Combination 2, on the other hand, has the advantage of sounder guarantees that the use of motive power will be duly related to the engineering points of view.

In both combinations, of course, there must be a close co-operation between Operation and Mechanical Engineering. In the day to day work this co-operation seems to be established generally by means of direct contact between organs at the same level of the organisation without going through the higher level where both of these main functions are joined.

In combination 2 the locomotive crews, when outside the locomotive depots, have to take orders from the operating staff in operational matters, but in mechanical matters still fall under the jurisdiction of the Engineering staff. Thus we have here a functional connection of the kind characteristic of a functional type of organisation.

Combination 1 is practised by American railways mentioned in this report.

Combination 2 is practised by :
British Railways;
Danish State Railways;
East African Railways and Harbours;
Finnish State Railways;
Swedish State Railways [1].

As to the functions *Signal Engineering and Telecommunications Engineering* at lower regional levels, these may be combined in the following ways :

1. Both functions are ranged under Permanent Way;

2. Signal Engineering is broken out from Permanent Way as a separate function;

3. Telecommunications Engineering is broken out from Permanent Way as a separate function;

(1) An exception is formed by rail-going buses and lighter motive power for shunting, which are ranged according to combination 1.

4. Both Signal Engineering and Telecommunications Engineering are broken out from Permanent Way and joined together;

5. Both Signal Engineering and Telecommunications Engineering are broken out from Permanent Way and separated from each other.

According to the answers received, the following combinations are to be found :

Combination 1 : Finnish State Railways;
Indonesian State Railways;
Norwegian State Railways.

Combination 2 : —

Combination 3 : East African Railways and Harbours [1].

Combination 4 : British Railways;
New York Central;
Pennsylvania Railroad.

Combination 5 : Swedish State Railways.

As regards *Main Workshops* it has been found that in some cases these are subordinated to the regional chiefs, whereas in other cases they are independent and centrally ranged. The latter form of organisation may have the advantage of facilitating the specialization of different Main Workshops.

The latter form of organisation is applied by the following railways :
Danish State Railways;
East African Railways and Harbours;
Finnish State Railways;
Indonesian State Railways;
Pennsylvania Railroad Company;
Swedish State Railways.

The Norwegian State Railways mention that a change to this form of organisation is being considered.

D. Geographical organisation.

1. Departmental and divisional organisation.

Only railway undertakings of a rather small size can be operated as a single managerial unit. In the case of railroads of larger size a geographical division of the territory must be made in order to confine the managerial units to an appropriate size. If the number of territorial units is small, the territorial units may be directly subordinated to the Headquarters. If the number of territorial units is larger, however, intermediate territorial units are often established between Headquarters and the smallest territorial units.

The co-ordination between the territorial units may be made according to two different main principles illustrated in figures 4 and 5 *a* and 5 *b* respectively. These two main principles are generally called departmental and divisional organisation.

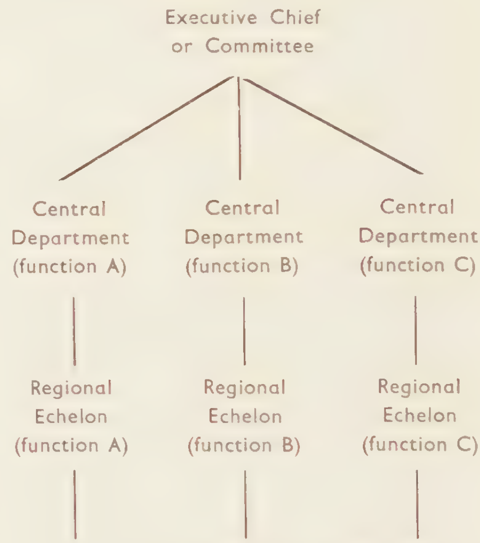
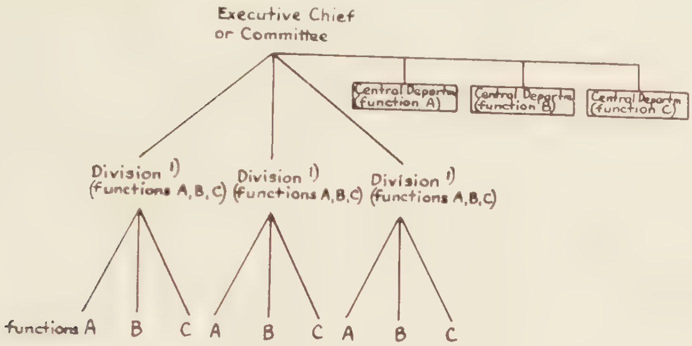


Fig. 4. — Departmental Organisation.

Under a departmental organisation each main function is the responsibility of a department extending from the top to the bottom of the railway organisation. This relies for its successful working upon frequent reports, interdepartmental co-operation and carefully designed working arrangements for co-ordination.

In a divisional organisation there is a ranking officer in command of each divi-

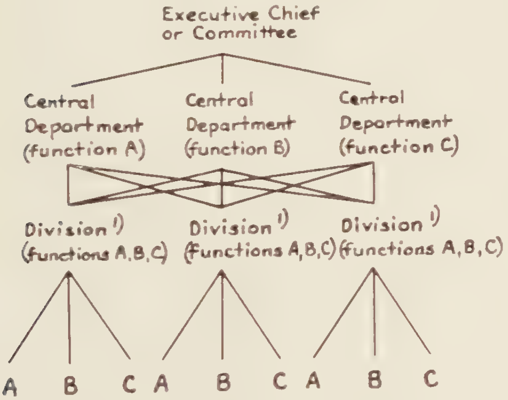
(1) Maintenance and construction of telecommunications are carried out by the East African Posts and Telecommunications Administration.



1) Also other names are used (Region, District, Section, etc.)

Fig. 5a. — Divisional Organisation. (Headquarters organised as a staff.)

sion (region, district). This arrangement places the responsibility for the divisional functions on him. He is assisted by special officers functioning as his staff.



1) Also other names are used (Region, District, Section, etc.)

Fig. 5b. — Divisional Organisation. (Functional connection between Headquarters and Divisions.)

Departmental and divisional organisation are more thoroughly examined in section D 5.

The answers received show that the different types of organisation are applied as indicated in the table on the following page.

As regards the *British Railways,* the organisation is not of a strictly departmental type. Within each Region there is a Chief Regional Officer, whose principal functions are as follows :

« i) to secure that the policies laid down and general instructions issued by the Railway Executive are made effective;

ii) to secure generally that the administration of the region is carried on economically and efficiently;

iii) as the representative of the Executive in his region, to contribute to the formation of general policies both by direct representation to the Executive and by being present at meetings of the Executive every fortnight;

iv) to secure the development of traffic and its safe, efficient and economical working in conformity with the general directions of the Executive;

v) to represent the region in public matters;

vi) to be responsible for the application of the policies of the Executive to the staff of all grades;

Type of territorial division	Railways applying the type mentioned in the first column	Size of railways	
		Length of line operated km	Number of staff
1 *a)* The territorial units come directly under Headquarters. The organisation is of *departmental* type.	Rhodesia Railways . . . . . . Finnish State Railways . . . . East African Railways	3 900 4 800 5 600	27 000 37 000 47 000
1 *b)* The territorial units come directly under Headquarters. The organisation is of *divisional* type.	Norwegian State Railways. . .	4 400	25 000
2 *a)* Between Headquarters and the smallest type of territorial units are larger territorial units. The organisation is of *departmental* type.	Egyptian State Railways. . . . New York Central . . . . . . British Railways (1).	3 500 17 300 31 100	— 109 000 600 000
2 *b)* Between Headquarters and the smallest type of territorial units are larger territorial units. The organisation is of *divisional* type.	Danish State Railways . . . . Indonesian State Railways (2). . Atlantic Coast Line. . . . . . Southern Railway System . . . Swedish State Railways . . . . Pennsylvania Railroad. . . . . Atchison, Topeka & Santa Fe. .	2 600 6 000 8 700 12 200 15 100 16 300 21 100	27 000 74 000 19 000 40 000 66 000 138 000 64 000

(1) The organisation of British Railways is not of a strictly departmental type. See further above.
(2) Certain of the territorial units of the smallest type are directly subordinated to Headquarters.

vii) to exercise general oversight of the work of departmental officers in his region who will meet together under his chairmanship;

viii) to co-ordinate the working of the departments at regional level in matters affecting more than one department;

ix) to act in liaison, where necessary, with corresponding officers of other Executives;

x) to deal with appeals from decisions of departmental officers on individual cases of discipline.

The Chief Regional Officer is responsible to the Railway Executive as a whole.

The regional departmental officers on matters of principle are responsible to and are directed by the appropriate members of the Railway Executive (the Chief Financial Officer in the case of the Accountant and the Treasurer).

The departmental officers in each region comply with the instructions of the Chief Regional Officer on all matters coming within his responsibilities, and give him loyal assistance and co-operation. »

Thus the departmental officers in each

Region report on the one hand to the Central Department in question and on the other hand to the Chief Regional Officer. Here, therefore, we have a connection which is typical of a functional organisation in the special sense of this term. This may be the reason, why the English organisation is often called functional.

2. **Territorial division.**

In order to give simply and clearly an idea of the extent of the territorial units, as well in respect of their size as of their functions and co-ordination, the following method has been chosen and used in chart 2.

For every railway for which sufficient information has been received a simplified organisation chart has been drawn up. In these charts only the following main functions have been taken into consideration : Operation, Commercial, Motive Power, Mechanical Engineering and Permanent Way. Each type of territorial unit embracing some of these functions has been marked on the chart as a rectangle. (In cases when statements are lacking the respective units are marked by a circle.) The base of the rectangle is proportional to the average personnel within the territorial units of the kind in question. Its altitude is proportional to the average length of line operated within the territorial units of the kind in question. The same scale has been used in all charts. As regards the Regions of the British Railways considerations of space, however, prevented the drawing of a rectangle in the scale chosen. When only the statement concerning length of line has been received, only the altitude of the rectangle has been marked.

At the base and altitude respectively of each rectangle the average personnel and length of line (in kilometres) has been indicated as an absolute number.

The surfaces have been grouped and connected with lines in order to show the connection between them and their relation to Headquarters.

Below the lowest category of territorial units the main functions of the different units have been stated. The following symbols have been used :

O_1 = Functions coming under Operation according to combination 1, p. 591/19;

O_2 = Functions coming under Operation according to combination 2, p. 591/19;

C_1 = Functions coming under Commercial according to combination 1, p. 591/19;

C_2 = Functions coming under Commercial according to combination 2, p. 591/19;

OC = Functions embraced by combination 3, p. 591 19;

Mo = Motive Power (Provision and Manning);

Me = Mechanical Engineering (except Provision and Manning of Motive Power); W = Permanent Way.

In chart 2 the organisation charts of the different railways have been brought together and statements have been given concerning the size and volume of traffic. These statements have been worked out on the basis of the information given according to appendix II of the questionnaire or — in those cases in which this appendix was not filled in — on the basis of the statistics of the UIC. The statements refer in most cases to the year 1951, in some cases, however, to a period of 12 months nearly but not quite coincident with 1951.

As a measure of the traffic volume the unit « traffic units » (= unités trafic) has been used, i.e. the sum of passenger kilometres and freight-ton-kilometres (metric tonne). This simple unit is often used in Europe in order to get a collective although very much simplified term for the volume of both passenger and freight traffic. (In reality traffic volume must also be said to depend on other factors such as average length of journey and of haul, kind of freight, etc., wherefore the figures given are not in all cases readily comparable.)

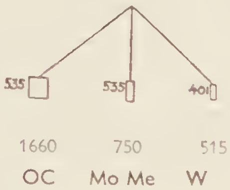
In the chart the different railways have been arranged in succession according to the number of traffic units.

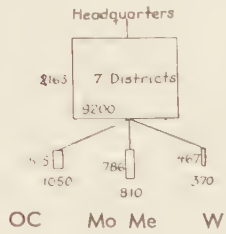
	East African Railways and Harbours	Norwegian State Railways	Indonesian State Railways
Territorial division	Headquarters OC Mo Me W	Headquarters 549 — 8 Districts 3300 OC Mo Me W	Headquarters 1558 [3 Regions[1] • 470 [3 Regions[2] OC Mo Me W 425 [11 Divisions OC Mo Me W *Note :* 1) Isle of Java 2) Isle of Sumatra
Traffic units, millions/year		2901	4063
Number of Staff	46730	25302	73972
Length of lines operated, km	5577	4389	6035
Traffic units per km of line, millions per year		0.7	0.7
Train-kilometres per km of line per year	2306	6407	4368

	Southern Railway System	Atchison, Topeka and Santa Fe	
Territorial division	Headquarters 3837 [3 Regions 641 [19 Divisions O_2 Mo Me W *Note :* C_2 is a separate function, outgoing from Headquarters	Headquarters 5268 [4 Grand Divisions 916 [23 Local Divisions O_2 Mo Me W *Note :* C_2 is a separate function, outgoing from Headquarters.	2 vic Op 5 Di G Divisio Supts. Note : Head ated from Supe distr of pa coac going
Traffic units, millions/year	29953	54224	
Number of Staff	40017	63549	
Length of lines operated, km	12180	21071	
Traffic units per km of line, millions per year	2.5	2.6	
Train-kilometres per km of line per year	4327	4326	

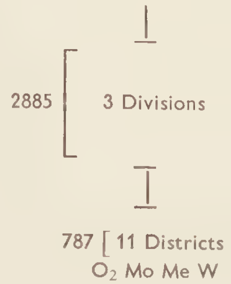
Chart 2. *Territorial division.* (Explanations, see text !)

...tate Railways	*Finnish State Railways*	*Swedish State Railways*	*Atlantic Coast Line*
...dquarters	Headquarters		Headquarters





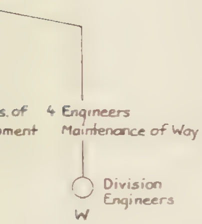
Note: Under the Districts are also 6 sections for Signal Egineering, 6 Sects for Telecommunications Engineering and 11 Sects for Electric Engineering.



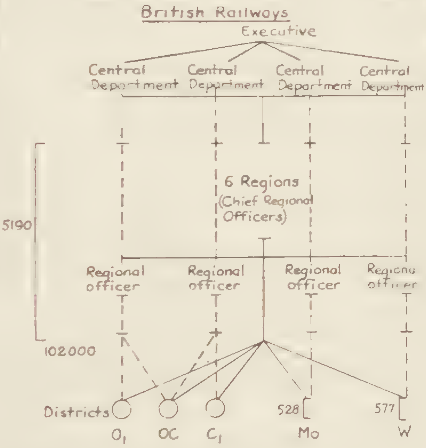
Note : C_2 is a separate function, outgoing from Headquarters.

4279	6702	15631	18114
6966	37235	65770	19450
2642	4775	15138	8655
1.6	1.4	1.0	2.1
3474	7656	8292	3293

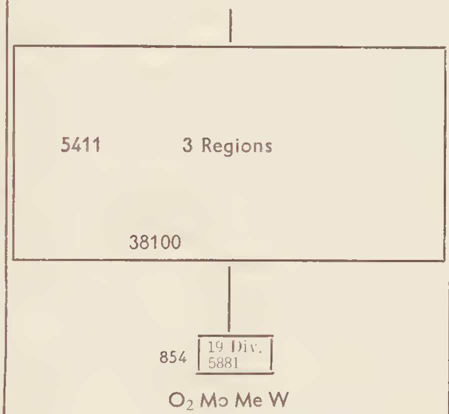
... Central	British Railways	*Pennsylvania Railroad*
...arters		Headquarters



...unction, outgoing from ...l Engineering is separ... ...nt Way and outgoing ... Presidents Operation. ...nt transportation and ... stock and supervision ...tation and provision of ...eparate functions, out... ...ters.



Note : In certain cases there are Divisions between Regions and Districts. There are 47 Operating Districts, 48 Commercial Districts and 13 Districts where Operating and Commercial are combined. Mechanical & Electric Engineering, Carriage and Wagon Engineering and Signal & Telecommunications Engineering are separate functions.



Note : C_2 is a separate function, outgoing from Headquarters.

...01	70894	91005
...81	599831	137604
...58	31145	16293
3.8	2.3	5.6
...46	19445	7491

3. Size of divisional units.

It seems to be of special interest to examine the size of the lowest territorial units, in which are joined the main functions Operation, Commercial, Motive Power, Mechanical Engineering and Permanent Way.

The table below shows the average size of the lowest territorial units of this kind in railways with the divisional type of organisation. The average size is stated on the one hand in the length of line operated, and on the other hand in the form of traffic units per territorial unit [1]. The different railways have been ranged according to the average length of line per territorial unit. In the last column the traffic volume has been indicated in the form of traffic units per kilometre length of line operated.

Railway	*Name of the territorial unit*	*Number of units*	*Average length of line per territorial unit*		*Average traffic units per territorial unit during 12 months (millions)*	*Average traffic units per km length of line during 12 months (millions)*
			kilometres	*miles*		
1	2	3	4	5	6	7
Swedish State Railways .... (SJ)	District	7	2 163	1 344	2 233	1.0
Danish State Railways .... (DSB)	District	2	1 321	821	2 140	1.6
Atchison, Topeka and Santa Fe ... (ATSF)	Local Division	23	916	569	2 358	2.6
Pennsylvania Railroad .... (PRR)	Division	19	854	531	4 790	5.6
Atlantic Coast Line (ACL)	District	11	787	489	1 623	2.1
Southern Railway System .... (SOU)	Division	19	641	398	1 576	2.5
Norwegian State Railways .... (NSB)	District	8	549	341	363	0.7
Indonesian State Railways .... (DKA)	Region Division	3 11	431	268	290	0.7
Weighed average			838	521	2 135	—

In figure 6 the values of cols. 4 and 7 have been marked in a system of coordinates. The notations correspond to those indicated in brackets in column 1 of the table above.

As will be clear from the diagram, one cannot discover any pervading, clearly pro-

[1] Data as to the number of personnel were not sufficient for reproduction here.

nounced relation according to which a smaller volume of traffic per kilometre line results in a larger size of the territorial units. Perhaps there are so many circum-

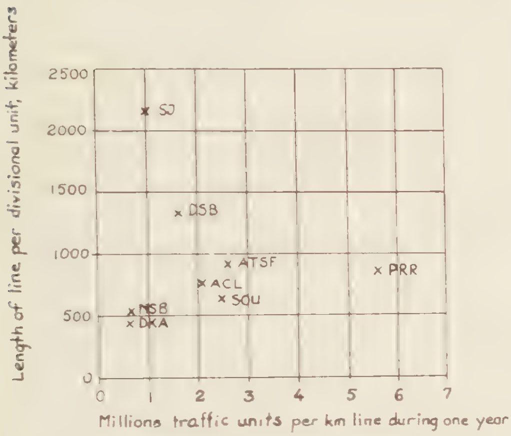


Fig. 6. — Relation between average size of divisional units (1) and average volume of trafic.

(1) Units at the lowest level, embracing the functions Operation, Commercial, Motive Power, Mechanical Engineering and Permanent Way.

stances having an effect on the territorial division that it is difficult to find any rules on the size. Possibly, however, this subject may be more exhaustively dealt with in the special report, where also the material in the hands of the French reporter can be used.

Where the smallest territorial units are brought together into larger territorial units under Headquarters, or where the organisation is wholly or partly of departmental type, such great variations are to be found that it is still more impossible to find any rules for the division into territorial units.

4. Principles of territorial division.

Besides the desideratum that the territorial units be given a suitable size, certain other wishes also enter in determining the territorial division. These wishes are partly incompatible with each other. The foremost of them are :

A. The division ought to be suitable from the operational point of view, implying, among other things;

that the border-lines between different territorial units are such that the need of daily co-operation is reduced to a minimum;

that geographically widely separated lines are not grouped together;

that the centers of the territorial units are located in such a way that contact between them and with Headquarters is facilitated;

that the centers of the territorial units are located in such a way that contact with subordinated organs is facilitated.

B. The division ought to be suitable from the public service point of view, implying, among other things;

that customers or authorities at a certain place will, if possible, only have to address themselves to one single regional railway authority;

that the centers of the territorial units are located in such a way that contact with the customers is facilitated.

In every division of railways into territorial units it has been attempted to find an appropriate balance between the abovementioned desiderata, which — as already stated — are not all combinable. According to which of these considerations have been put in the first place, different forms of division have developed. When a railway system is an amalgamation of two or more previously separate railways, the previous boundaries have often been wholly or partly decisive for the division of the consolidated system. Furthermore, the supply of telecommunications and buildings for administrative purposes and the general technical standard of permanent way and equipment may have affected the territorial division.

Two principal types of division into *larger* territorial units are found, viz. :

1. The territorial division follows the lines of the chief arteries. As a rule, this means, that the Regions (Districts, Divi-

sions) radiate in sectors from the city where the Headquarters are located.

2. The centres of the territorial units have been located in different parts of the country and in places that are of importance from railway, mercantile, industrial or public administrative points of view. Round these centers suitable territorial units have been separated.

Below we shall investigate a little more closely the way in which these types of division meet the desiderata stated at the beginning of this section.

The requirement that the border-lines between different territorial units be such that the need of daily co-operation is minimized is met in both types, but in different ways. In a division according to point 1 the need of co-operation regarding the train movement is reduced to a minimum. But the need of co-operation regarding the station work at the place where the lines radiate becomes greater. Where this type of division is found, however, the lines at this central point usually radiate from different stations, and the different territorial units are therefore rather well separated also at this point.

In a division according to point 2 the need of co-operation becomes greater regarding the train movement. The need of co-operation as regards station work, on the other hand, becomes rather small, provided the border-lines are drawn in a suitable way.

The desideratum that geographically widely separated lines shall not be brought together is usually better met in a division according to point 2 than in one according to point 1.

The different desiderata, as to the location of the centers of the territorial units are uncombinable.

In a division according to point 1 the offices of the territorial units may be located in the same place as Headquarters. If this is done, a close mutual contact and a close contact with Headquarters may be attained, but the contact with subordinate organs and with customers outside this place will not be so easy.

In a division according to point 2 the mutual contact and the contact with Headquarters will be more difficult, but the contact with subordinate organs and with customers out in the country will be facilitated.

Finally, as regards the requirement that customers or authorities at a certain place should, if possible, only have to address themselves to one single regional railway authority, this can, of course, never be fully met, as every territorial unit has a restricted sphere of activity. The division of one place between different territorial units, which is a consequence of a division according to point 1 seems from this point of view to favour a division according to point 2. But of course, the possibility of applying to a central authority is always open.

It may be said, in general, that a division according to point 2 presupposes a higher degree of uniformity in respect of technical standard and operational practice than one according to point 1. Where a division according to point 1 is found, the railway system is as a rule an amalgamation of previously separated railways radiating from a central point. In such cases it has been necessary to incorporate the separate railways in the greater system with smallest possible changes. Not until a higher degree of uniformity has been reached is there any reason to discuss the alternative form of division.

From the answers received, it is clear that:

Division according to point 1 is practised by the British Railways, but not strictly so, as the Scottish and the North Eastern Region seem to represent a division according to point 2.

Division according to point 2 is practised by:

Atchison, Topeka & Santa Fe;
Danish State Railways [1];
Indonesian State Railways [1];
Pennsylvania Railroad;
Swedish State Railways.

[1] The fact that the railway system serves different islands, makes such a division inevitable.

Southern Railway System has a combination of division according to points 1 and 2. Its Regions follow the chief arteries, but the network does not radiate from a central point. Headquarters have been located in Washington, which forms the north-east terminus of the system.

5. **Discussion of the principles of departmental and divisional organisation.**

In recent years there has been a lively discussion, especially in Great Britain, concerning the advantages and disadvantages of departmental and divisional organisation. The *background* of this discussion seems to be clear from the following abstract of an address by Mr. A. J. PEARSON, reproduced in « Modern Transport » 1952 : 11/8.

« The L.N.E. was organised on a divisional (or regional) basis with a general manager in charge of each. These divisional general managers were charged with the immediate conduct of the business, and there was a chief general manager at headquarters. There were, however, at headquarters some technical officers with system departmental control, and this feature of the organisation became more pronounced during the last war. Thus the L.N.E. organisation was inclining towards the departmental method within the regional system.

The other three groups, the L.M.S., G.W. and Southern, were organised on strictly departmental lines from headquarters, that is to say the chief departmental officers at headquarters controlled their departments throughout the systems and there were no regions. In all cases there was a general management in charge of each undertaking and the departmental system began below this.

B. R. ORGANISATION.

The next step in the process of development occurred when the four groups were unified in 1948 as « British Railways ». It was then decided to extend the departmental system to the very top, making the departmental officers and a chairman of general-manager experience, with two part-time members, into a Railway Executive with collective (or equal) responsibility for general management.

. . . .

Because of the tremendous aggregation of transport facilities which unification brought about, it was necessary, as in the foreign examples quoted, to divide the railways up into regions, each of which was in charge of a chief regional officer, whose principal duty was to co-ordinate the work of the departments in his region. Thus between the departmental control from the top and the regional co-ordination function, a departmental officer had a dual responsibility. »

In order to bring out points of view on the departmental and divisional types of organisation, the following two *questions* were included in the questionnaire.

« What are the advantages and disadvantages of an organisation in which all the responsibility falls upon a single officer in a given territorial zone ?

What are the advantages and disadvantages of an organisation in which all the responsibility in a given zone, falls upon different officials according to the Department ? »

Before the answers to these questions are discussed, the following may be pointed out.

The difference between a departmental and a divisional organisation is — as we know — that the responsibility for the co-ordination between different functions is placed at different levels. In a strictly departmental organisation this responsibility is placed at the highest level, in a divisional organisation the co-ordination takes place at lower levels.

A small railway has little need of co-ordination below the highest level. Thus a departmental organisation is natural here. As a matter of fact a smaller railway corresponds to the smallest units of a

larger railway system, which units also are organised in a departmental way. Thus it is only with reference to larger railway systems that the discussion concerning departmental or divisional organisation is justified.

As far as is known, no-one has ever defined the functions that must be combined in divisional units if the organisation is to deserve the name of divisional organisation. In this report the name divisional organisation has been used when the main functions Operation, Commercial, Motive Power, Mechanical Engineering and Permanent Way are brought together in regional units under the guidance of one single chief, solely responsible to the higher echelon for all these functions. Within this framework, however, considerable variations are to be found. Certain part-functions, normally included in the above-mentioned main functions, may in certain cases be broken out and organised along departmental lines. Other functions than the above-mentioned main functions may in certain cases be included in the divisional organisation, and in other cases be organised along departmental lines.

In view of these great variations, the questions quoted above have been given a very general wording, but they may nevertheless point to the essential question.

British Railways, that are perhaps best qualified to throw light upon the subject, have answered that « in view of the proposals for the re-organisation of British Railways now before Parliament, it would be inappropriate to comment on these questions. »

The question « What are the advantages and disadvantages of an organisation in which all the responsibility falls upon a single officer in a given territorial zone? » is answered by *the Pennsylvania Railroad Company* in the following way, which covers several answers given by other railways.

« Assuming that the authority vested in such officer is commensurate with the responsibility placed upon him, the advantages of this form of organisation are that it provides for expeditious and fully correlated decisions issuing from that source.

Thus, where the ranking Operating Officer combines the functions of Transportation, Road Maintenance, and Equipment Maintenance, as well as those of minor units, it is not necessary to secure the approval of other officers of equal rank as a precedent to promulgating decisions affecting any one or all the units subordinate to him.

Being responsible, as he is, for the successful, efficient and economical administration of all subordinate units within his jurisdiction, he will be sure that decisions intended primarily for the benefit and government of one unit will not conflict with, or be to the detriment of the others, for which he is equally responsible. « His left hand will know what his right hand is doing », because both are integral and inseparable members of the same body.

The preliminary assumption, of a commensurate balance between responsibility and authority, is essential.

The disadvantages that may be argued as being inherent in this form of organisation are that, in theory, the ranking officer must be familiar with all details of every subordinate unit, whereas from a practical standpoint that is not possible.

In rebuttal to that argument it is urged that over-all responsibility is a stimulus to acquiring a broader knowledge of the principal functions and activities of the several units. Minor details are delegated to the Lieutenants in direct charge of those units, and in whom a similar, equal, measure of authority and responsibility is placed. »

The following statement by the *Swedish State Railways* may be appended here.

« From the point of view of the customers and public authorities it is an advantage if there are regional chiefs with authority over the most important functions.

As a disadvantage of a divisional organisation one may mention that a certain

lack of uniformity between different divisional units may arise. Furthermore certain functions in a divisional organisation might require more echelons and more staff than if they were organised along departmental lines. »

The question « What are the advantages and disadvantages of an organisation in which all the responsibility in a given zone falls upon different officials according to the Department ? » is answered by the *Pennsylvania Railroad Company* in the following way :

« The advantages of an organisation in which the responsibility, in a given zone, falls upon several officials, according to the Department, would appear to be in the concentration of effort, and the freedom from interference, in a single phase of activity.

This, in effect, is the form actually existing at lower levels in the form of organisation discussed above, except that now individual departmental control extends to executive levels.

It may be contended that there is consistency in following the same general organisational plan at all levels, but opponents of this philosophy will urge that it induces frictions which must eventually be reconciled by a single, over-all authority. »

Atlantic Coast Line answers :

« The disadvantage in this is that officials of different departments might have varied opinions and no definite conclusions could be arrived at on matters of importance where overlapping authority and functions often play an important part. Further, lack of uniformity in carrying out higher Managerial policies. »

The Swedish State Railways adds :

« The advantages of a departmental organisation seem to be that an expert is responsible for each function, and that each function or group of functions can be given the most appropriate organisation.

Disadvantages seem to be, that a too high degree of specialization must be inappropriate and that the organisation becomes complicated from the public point of view, as the public in different matters have to address themselves to different regional officers, whose territorial zones are perhaps also different. »

The Finnish State Railways writes:

« As an advantage of the present centralized organisation we might mention that the Central Offices are always conscious of what is done in the line administration and can easily give orders and directions to any local establishment. »

As an example of considerations in the choice between departmental and divisional organisation the following abstract of the answer from *East African Railways and Harbours* may be quoted :

« This Administration has no experience of an organisation in which all responsibility falls upon a single officer in a given territorial zone, but the question of setting up such an organisation was considered following the amalgamation of the Kenya and Uganda Railways and Harbours and the Tanganyika Railways and Ports Services in 1948, when it was suggested that the former Tanganyika Railways should be operated as a region of the amalgamated system under the control of a regional manager responsible for the work of all Departments. This would have meant either that all instructions, including technical instructions on matters affecting only one Department, from Headquarters Heads of Departments to District Officers, would have to be passed through the officer in charge of the region, which would have placed an additional link in the chain of command and entailed the placing of technical officers under a non-technical head, or if this was not done, that the officer in charge of the region could not asssume full responsibility for the working of the region, because his District Officers would be receiving instructions direct from their

Heads of Departments at Headquarters. It was considered necessary for efficiency and the maintenance and raising of the standard of working generally, that each Head of Department should retain responsibility for the efficient conduct of the work of his Department throughout the Administration, for which he would require to deal direct with his District Officers, and it was, therefore, decided that the departmental type of organisation should continue, but that one officer should be designated as the Administration's representative in Tanganyika to provide liaison with the Government and commercial community. As already stated in reply to questions 10 to 12, however, this officer has no executive authority over officers of other Departments.

The organisation set up in Tanganyika has been the subject of considerable criticism in that territory, but exhaustive enquiries have shown that in East African conditions there was no practicable alternative, and that whatever the framework of the organisation no greater degree of local autonomy could in practice be given. On the Administration as a whole, the present departmental organisation is considered to be the only system which could function economically and efficiently at the present stage of development. »

Judging from the available evidence, the development within larger railway systems seems to tend towards organisations of a divisional type. However, a tendency to preserve a certain degree of departmental control may in several cases be traced. The organisation of *British Railways* is founded on a high degree of departmental control. The same is the case as regards *Pennsylvania Railroad*, that writes the following :

« The organisation of the Operating Department of the Pennsylvania Railroad is basically Regional and Divisional, as opposed to Departmental. As a means to overcoming some of the difficulties that might otherwise obtain, there is a secondary line of control extending department-wise from the System offices down to the Regions, and from Region to Division. Through this process, broad matters of policy and budget are developed at the higher levels, approved and correlated by the ranking System or Regional officer, and their execution follows up through both lines of control.

Such a system has been demonstrated to be both fast wheeling and relatively frictionless. Heavy repairs have not been found necessary. »

Without having clear verification of this statement in the answers, it might be assumed that many railways with the divisional type of organisation have preserved a certain degree of departmental control.

Of the larger railway systems which have been referred to in this report, *New York Central* is the one that has preserved the highest degree of departmental organisation. It must, however, here be pointed out that the question as to whether the organisation of New York Central is to be regarded as being of departmental or divisional type, is a question of definition. With the sense in which the terms have been used in this report the organisation is departmental, as the functions Mechanical Engineering and Permanent Way separate from Operation at Headquarters' level. Operation and Motive Power, however, are brought together in an organisation of divisional character.

E. Number of administrative (1) personnel.

In order to try to ascertain the number of administrative staff at different railways, certain statements concerning the number of staff during 1951 have been requested in Appendix II of the questionnaire.

In order that the statements should be as far as possible comparable, they have been restricted to the pure railway service.

(1) In this and the following chapter the words administrative and administration are used as comprehensive terms, referring both to administration and to management.

To draw a clear border-line between administrative staff and other staff is very difficult. It is, however, quite evident that the staff at Headquarters and higher regional levels should be ranged under the first category as well as that the staff at the local establishments should be ranged under the latter category.

The intermediate categories of staff, however, are often difficult to classify, especially as sometimes certain of their tasks may be administrative, and others not.

In view of this fact, and in order that the railways receiving the questionnaire should not be caused too much work the following simplification was devised : statements were requested as to the number of personnel *a*) at Headquarters, *b*) attached to other managerial units (with the exception of local establishments and the smallest units concerning fixed installations), and *c*) within the whole railway system.

The different answers are tabulated in the table below. The table has also been provided with supplementary statements of

Railway	*Number of personnel*			*Percentage of total personnel*			*Traffic units during one year (millions)*
	Head-quarters	*Other managerial units*	*All system*	*Head-quarters*	*Other managerial units*	*Col 5 + 6*	
1	2	3	4	5	6	7	8
Finnish State Railways .... (FSJ)	750	700	37 235	2.0	1.9	3.9	6 702
East African Railways	59	1 821	46 730	0.1	3.9	4.0	(3)
Danish State Railways .... (DSB)	690	479	26 966	2.6	1.8	4.3	4 279
Swedish State Railways .... (SJ)	1 640	1 820	65 770	2.5	2.8	5.3	15 631
Norwegian State Railways (1) .... (NSB)	488	1 014	25 302	1.9	4.0	5.9	2 901
Indonesian State Railways .... (DKA)	1 814	3 659	73 972	2.5	4.9	7.4	4 063
Southern Railway System .... (SOU)	2 096	1 257	40 017	5.2	3.1	8.4	29 953
New York Central .. (NYC)	11 919	5 000	108 981	10.9	4.6	15.5	66 201
Atlantic Coast Line........	1 350	(3)	19 450	6.9	(3)	(3)	18 114
British Railways	(2)	(2)	599 831	(2)	(2)	(2)	70 894

(1) According to the UIC statistics.
(2) Down to Divisional office level inclusive — 24 728 (4.1 %).
(3) No statement received.

the volume of traffic during 1951 (or the nearest corresponding period of 12 months). The volume of traffic has been expressed in traffic units.

Though we are quite aware that this implies a considerable approximation, the figures in column 7 above will in the following be called « Percentage of administrative staff ».

It would not be justified to make a direct comparison between the numerical values of the percentage of administrative staff, as of course both the size of a railway and its volume of traffic have an effect upon the need of administrative staff.

An attempt to make correlations of this kind has been made in figure 7, where the values of cols. 7 and 8 in the table above have been marked in a system of co-ordinates. The notations correspond to those stated in brackets in column 1 of the table.

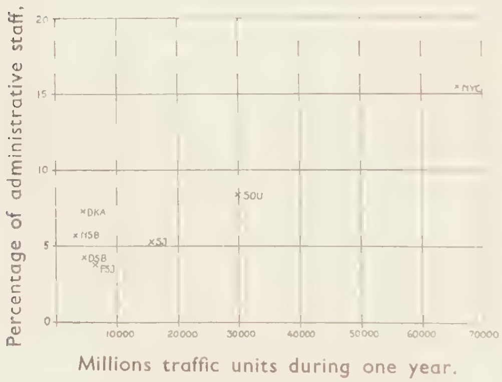


Fig. 7. — Relation between Percentage of administrative staff and Volume of traffic.

The fact that the points representing FSJ, SJ, SOU and NYC practically form a straight line may be a mere chance.

The material in hand is not sufficiently comprehensive to allow of any conclusions as to what may be considered to be the *normal* percentage of administrative staff. However, this subject may perhaps be more exhaustively dealt with in the special report, where also the material in the hands of the French reporter can be used.

An attempt has been made to bring forth completing figures of the percentage of administrative staff out of the UIC statistics. The only completing figures available as regards countries to be dealt with in this report have reference to the U.S.A. According to this statement the average percentage of administrative staff in all railways of the U.S.A. is about 20 %. The explanation of this high percentage may be that a far advanced technical rationalization requires a large administration and — at the same time — reduces the personnel for « the actual work ».

In his work « Shop Management », published in 1911, F. W. TAYLOR, one of the pioneers of Scientific Management, has written :

« The belief is almost universal among manufacturers that for economy the number of brain workers or non-producers, as they are called, should be as small as possible in proportion to the number of producers, i.e. those who actually work with their hands. An examination of the most successful establishments will, however, show that the reverse is true. »

Nowadays the need for « brain workers » is generally acknowledged. It is also evident, that to exceed the minimum administrative staff determined by the necessity of managing the traffic in a satisfactory way is legitimate in order to accelerate technical, organisational and economical progress. How far this minimum may be exceeded is possibly in the main a question of economic resources.

F. Simplification and retrenchment of the administration of railways.

All the preceding exposition has aimed at showing different possibilities of simplification and retrenchment of the administration of railways. In this chapter will be given examples of certain steps taken or planned to this end by some railways.

In the answers received several railways declare that they pay a great deal of attention to all possibilities of improving their organisation, but do not discuss the matter in any further detail. On the whole, the answers are rather brief, which is quite understandable, as detailed answers would in most cases have entailed very extensive work.

For this reason, these questions must also be rather summarily treated in this report. Below, the different steps are grouped under certain comprehensive headings.

Centralization of work.

A centralization of certain kinds of work previously performed at different places may often make the work more efficient. The staff can be more specialized and possibilities of better output are increased. A further advantage is that other officers are relieved of functions of a special nature.

Typical examples of work suitable for such centralization are to be found within the field of statistics, design, payment of pensions, purchases, printing.

The institution of special organs for studies of rationalization and simplification of method is reported by the Finnish, Norwegian and Swedish State Railways. A central psychotechnical laboratory has been instituted by the Finnish State Railways.

Amalgamation or regrouping of functions.

An amalgamation or regrouping of different organs at Headquarters or the regional administration may sometimes involve simplification or retrenchment of the administration.

The following steps of this kind are reported :

The Swedish State Railways have recently combined in one central department two previously separate departments for passenger and freight transportation matters. The amalgamation of two previously separate departments for passenger and freight commercial matters is also being realized.

One step dating back, certainly, to 1928 but nevertheless worth mentioning here, is the amalgamation into districts of formerly separate regional departments, thus a change from departmental to divisional organisation.

The Norwegian State Railways observe that an amalgamation of the Traffic and Operating Departments is being discussed.

The Finnish State Railways write as follows :

« In 1947 the Ministry of Communications set up a Committee responsible for the study of the factors capable of having an influence on the profit possibilities of the State Railways, as well as for the examination of the possible alteration of their administrative organisation. The Committee completed its tasks in March, 1949. In its report the Committee recommends the transformation of the State Railways into a more independent undertaking and a fuller application of commercial principles to their management. In its opinion, it would be necessary to create, outside the State budget, a « State Railways Fund », with distinct social and operating capitals. Above the General Management, a Board of Directors would have to be constituted. The administration of the system would be ensured in the first stage by Regional Officers, with rather extensive powers. The eight various Departments of the Central Administration would be combined in four main Departments. At the same time the staff position would have to be based on private instead of public laws. — The proposals of the Committee gave rise, however, to criticism and opposition, especially on the part of the staff, and the question of reorganisation is therefore still unresolved. — Recently a more modest suggestion has been made as to the regrouping of the Central Departments; i.e. the tasks of the Economy Department should be divided up between the Tariffs Department (Accountancy Section of the E.D.) and the Administrative Department (Economy

& Staff Section of the E.D.). In this connection the Tariffs Department should also be given a more adequate name (e.g. Economy & Commercial Department).

A plan for the reorganisation of the main workshops has also been prepared by a Committee with more restricted tasks appointed by the Ministry of Communications soon after the above-mentioned large Committee had completed its task. This plan, which provides for the setting up of an undertaking to manage the workshops, or at least ensure the independence of the workshop accountancy, has also been severely criticized by the staff representatives. Consequently re-organisation studies remain in abeyance. »

Revision of the geographical extent of certain managerial levels.

Where the size of territorial units can be increased without any or with little increase of the administrative staff, and without neglecting the demand for efficient direction and control, a reduction in the number of territorial units may be profitable.

The following steps of this kind are reported :

The Pennsylvania Railroad Company writes :

« Prior to May 1, 1949, the New York Division and the Long Island Railroad, the latter being also operated as a Superintendent's Division, comprised the territory designated as the New York Zone, under the jurisdiction of a Regional Vice-President, a General Manager, and their respective staffs. With the separation of the Long Island Railroad from the Pennsylvania, the New York Zone was abolished, and the New York Division absorbed in the Eastern Region.

Commencing October 1, 1949, and continuing progressively through 1950 and 1951, nine General Superintendents' Divisions and eight Superintendents' Divisions were abolished. The territories contained in the abolished Superintendents' Divisions were absorbed by the remaining Divisions, which were reduced to a total of eighteen. General Superintendencies were eliminated entirely, and all Superintendents now report directly to their respective General Managers.

In addition to the direct economies produced through the reduction in officer and staff personnel, the direct channelling of matters between General Managers and Superintendents has greatly increased the efficiency of both administration and operation.

Enunciation of the policy that « The Superintendent is General Manager of his Division » has clarified the Authority and enhanced the prestige of the Superintendent and has produced additional beneficial results of marked degree. »

The Swedish State Railways are in 1953 realizing a reduction of the number of Districts from 8 to 7. Also a reduction of the number of Sections (level next below Districts) is to be realized.

The Finnish State Railways remark that « some adjustments have been recently effected as to the geographical extent of the Permanent Way Sections as their number was reduced from 13 to 12. Last year the Motive Power Sections (former 4 Depot Sections, divided in 11 depot districts altogether) were also reorganised and made to coincide with the Traffic Sections. »

Elimination of intermediate levels.

If an elimination of intermediate echelons is possible, this usually means both simplification and retrenchment of the administration.

An example of such an elimination has already been given above by the Pennsylvania Railroad Company. Another example is given by *London Transport*, who writes :

« The most important recent change in organisation has been the elimination of one step in the chain of command. There

were formerly two railway divisions each sub-divided into 2 districts. These districts have now been reformed into Divisions, each of them responsible to the Operating Manager (Railways) and the former divisions have been abolished. The advantages of this system, which have been realised in practice, are :

i) a reduction in the number of supervisory officials required;

ii) a reduction in the number of steps in the organisation, making it possible to transmit decisions, obtain information, etc., more quickly. »

The Swedish State Railways say that the fact that Main Workshops and Stores have been broken out from the divisional organisation and ranged directly under Headquarters means an elimination of the Chiefs of Districts as intermediate echelons in these matters. (This organisation was carried through as regards Main Workshops as early as in 1918 and as regards Stores in 1932.)

The Swedish State Railways also point out that in certain routine matters the current arrangement implies that the district level normally does not intervene. This applies for instance to the daily distribution of freight stock and the weekly distribution of passenger carriages. In these and several other matters direct communication takes place between the Central Departments in question and the Sections (level next below District).

Concerning orders, the procedure often adopted is that an order from Headquarters is addressed to the District Chiefs, but is sent at the same time also to those organs under the District Chiefs whom the order concerns. With this procedure the District Chief is kept informed, but does not intervene except in special cases.

The Swedish State Railways also mention that they have discussed a form of organisation involving smaller Districts and with the Chiefs of Sections stationed in the District Offices. This would practically abolish the Section level. For the present this organisation is being tried in one district. However, no such advantages of this organisation have appeared as to make a change to this form of organisation seem probable.

The Norwegian State Railways mention that the centralization and specialization of workshops are being studied. One of the reasons for such a step might be to eliminate the District Chief as an intermediate level between Headquarters and the Workshop Chiefs.

The institution or elimination of organs for special duties.

The institution of special organs for certain functions may sometimes bring about simplification or retrenchment of the administration. Certain such steps have already been mentioned in connection with the centralization of work. Here, therefore, only certain steps of this kind with reference to the regional organisation will be touched upon.

During the last few years *the Swedish State Railways* have broken out from the Permanent Way Sections the functions Signal Engineering, Electrical Engineering and Telecommunications Engineering and — under the Districts — instituted special Sections for each of those functions. These Sections are considerably larger than the Permanent Way Sections as regards the geographical size.

The reasons for this step are on the one hand the special technical character of these functions, and on the other hand the far-reaching electrification and the extensive telephone-net of the Swedish State Railways.

The elimination of organs for special duties may also sometimes bring about simplification and retrenchment of the administration. However, no steps of this kind are exemplified in the answers.

Decentralization of authority and work.

A too high degree of centralization has disadvantages, wellknown and manifest to everyone. Every railway therefore aims

at placing authority at the lowest possible level. From time to time investigations are made as to what steps towards decentralization might be realized. The extent to which decentralization is possible and practically feasible is dependent inter alia on the level of education of the staff, its mentality and that of the management.

No examples of steps aiming at decentralization will be given here, as the examples would not be of any general interest. Most measures of this kind refer to such details in the administration as are made in different ways by different railways. This is natural, as of course authority in more important matters must be kept central. The fact that decentralization refers mainly to matters of detail, however, means no depreciation of its value, as a reduction of the load of work at the higher levels is always of great value.

Simplification of administrative working methods and elimination of administrative work.

Besides the organisational changes of various kinds already mentioned, a careful examination of the administrative work may also result in simplification of the work and retrenchment of staff.

This is only mentioned here for the sake of completeness, but possibly falls outside the subject for this report.

III. SUMMARY.

In its introductory section the report deals with some organisational matters of a more general nature. The importance of an appropriate horizontal division of functions and an appropriate vertical division of responsibility and authority is emphasized. In the division of functions it is important to consider those functions which are especially vital, and to bring adjacent functions together. In connection with the vertical division it is important that clear definition of responsibility be given, that responsibility be combined with the corresponding authority, that the smallest number of levels be established and that authority be placed as closely as possible to the point where action originates. Furthermore the need for efficient co-ordination and control is pointed out and the importance of the number of subordinates to a chief being limited to an adequate number.

The different principal types of organisation are described and elucidated from certain points of view.

After this general introduction the writer proceeds to deal with the organisation of railways. First it is emphasized that the general principles and points of view already given are also applicable to a railway undertaking, but that certain circumstances complicate the organisation of railways.

In different chapter the vertical division of responsibility and authority and the horizontal division of functions are dealt with and — as the result of both these dovetailing divisions — the geographical organisation.

When dealing with the division of responsibility and authority the writer starts from a division into different levels of authority made by the American H. A. HOPF, and distinguishes the following four levels of authority :

Levels of authority	*General function*
Owners	Ultimate control
Administration . .	Administrative control
Management. . .	Business direction
Performance . . .	Routine performance

An account is given of different methods of arranging for ultimate control and administrative control.

The horizontal division of functions is dealt with in two sections. In the first, the grouping of functions at Headquarters is discussed. Here a summary is given of the different ways in which the respective railways have grouped the functions. In the

second section the grouping of functions within regional organs is discussed. Here the writer has dealt mainly with some more important differences between different railways, besides which the advantages and disadvantages of different groupings are discussed.

In the chapter « Geographical organisation » the two principal types of organisation, departmental and divisional, are first described. This is followed by a summary of the territorial division of different railways. This summary, in the form of simplified organisation charts, is intended to show the size of territorial units, their functions and their interconnections, as well as their connections to Headquarters. In special sections the size of divisional units and the principles of territorial division are discussed. Finally, this chapter includes a discussion of the principles of departmental and divisional organisation. Here the writer emphazises that the question of departmental or divisional organisation has no relevance for small railways. In larger railway systems development seems to tend towards organisation of a divisional type, but tendencies to preserve a certain degree of departmental control may be traced within organisations of a divisional type.

In a special chapter an attempt has been made to ascertain the number of administrative staff within different railway systems. The writer points out, however, that the material in hand is insufficient, but hopes that the special reporter will be able to deal in greater detail with this question in the special report, where also the material in the hands of the French reporter may be used.

In the last chapter. « Simplification and retrenchment of the administration of railways » it is emphasized that all that has gone before has aimed at showing different possibilities of simplification and retrenchment of the administration. The main purpose of this chapter has been to exemplify some steps to this end, taken or planned by different railways.

* * *

The conclusions of the reporter can be summed up in the following way :

1. The principles of geographical and functional organisation vary appreciably in different railway systems.

2. There are no general objective methods to determine whether a certain form or organisation or even a detail in a certain form of organisation is better than another alternative. Only deep-going analyses on the application of different principles of organisation in every special case can give an objective decision.

3. The subjective methods used in some parts of this report have not given any absolute proof that a certain form of organisation, or even a detail in a certain form of organisation, is decidedly better than another alternative. As a rule every form of organisation has special advantages and disadvantages, which must be weighed against the advantages and disadvantages of another form of organisation. The same applies to the details of an organisation.

4. Every railway must base its choice between different alternatives on its own judgement. In this connection, however, the experiences of other railways ought to be observed.

5. The following general principles apply to the organisation of a railway system.

a) The different functions should be established and divided up horizontally within the organisation in most suitable way. The importance of vital functions should be emphasized. Adjacent functions should be brought together under one and the same control.

b) Responsibility and authority should be combined, divided up vertically in the most suitable way, and clearly defined. Authority should be placed as closely as possible to the point where action originates. The smallest number of levels should be established. The clearest possible distinction should be drawn between the general functions : ultimate control, administrative control, business direction and performance.

c) Efficient co-ordination and control must be provided for.

d) The number of subordinates to each chief must be limited to a convenient number.

e) The territorial units should be given a convenient size and geographical composition.

6. Every organisation must be constructed taking into consideration the level of education of the staff, its mentality, and that prevailing in the country in question. The organisation should aim at getting from everybody the best he can give in work and in planning for the organisation.

7. In order to accelerate progress, there are certain reasons for exceeding the minimum of administrative staff determined by the necessity of managing the traffic in a satisfactory way.

8. An examination of the organisation should take place continuously or at not too long intervals, in order to take advantage of possibilities of simplification and improvement of the administration and such retrenchment as may be made without decreasing the effectiveness or the rate of progress. In this connection steps of the following kind should be considered :

a) Centralization of certain kinds of work;

b) Amalgamation or regrouping of functions;

c) Revision of the geographical extent of certain managerial levels;

d) Elimination of intermediate levels;

e) The institution or elimination of organs for special duties;

f) Decentralization of authority and work;

g) Simplification of methods for administrative work;

h) Elimination of administrative work.

CONTENTS

I. General organisation 573
A. General view 573
B. Principal types of organisation 574

II. Organisation of railways 578
A. General 578
B. Division of authority and responsibility (Vertical division) 579
1. Levels of authority 579
2. Ownership — Ultimate control 579
3. Determination of policy — Administrative control 582
4. Business direction 586
5. Performance 587
C. Functional organisation (Horizontal division) 587
1. General 587
2. Grouping of functions within Headquarters 590
3. Grouping of functions within regional organs 591
D. Geographical organisation 592
1. Departmental and divisional organisation 592
2. Territorial division 595
3. Size of divisional units 598
4. Principles of territorial division 599
5. Discussion of the principles of departmental and divisional organisation 601
E. Number of administrative personnel 604
F. Simplification and retrenchment of the administration of railways 606

III. Summary 610

English comprehensive terms			*Main functions included in the English terms*	*American comprehensive terms and main functions usually included in these terms*				
				Operation	*Transportation*	*Mechanical*	*Maintenance of Way*	*Traffic*
Traffic	Commercial		Fares, rates and charges					
			Goods depots.					
			Booking offices, parcels offices, reservation offices and other duties at passenger stations outside the duties of platform staff					
			Sales promotion.					
			Private sidings, warehouse accommodation					
			Claims					(1)
	Operation		Train movement					
			Shunting and other external operation at stations, yards and goods depots	×				
			Provision of coaching stock	×				
			Distribution of freight stock					
		Motive power (2)	Provision of motive power					
			Manning of locomotives					
			Servicing and depot maintenance of locomotives.					
Locomotive Engineering			Construction of motive power . . .					
			Workshop maintenance of motive power	×				
Carriage and Wagon Engineering			Construction of carriages and wagons					
			Maintenance of carriages and wagons	×				
Civil Engineering			Construction of permanent way, bridges, buildings —					
			Maintenance of permanent way, bridges, buildings					
Signals and Telecommunications Engineering			Construction of signals and telecommunications —					
			Maintenance of signals and telecommunications					

(1) Sometimes claims are referred to « Operation », sometimes to the central Law Department.
(2) Joint responsibility.

[656 .254]

INTERNATIONAL RAILWAY CONGRESS ASSOCIATION

16th. SESSION (LONDON, 1954).

QUESTION 5.

Radiophonic communications in railway working.

REPORT

(America (North and South), Australia (Commonwealth of), Burma, Ceylon, Denmark, Egypt, Finland, India, Indonesia, Irak, Iran, Republic of Ireland, New Zealand, Norway, South Africa, Sweden and the United Kingdom of Great Britain and Northern Ireland and the territories for whose international relations the United Kingdom is responsible),

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INTRODUCTION.

This question has not previously been the subject of a report to a meeting of the Congress as it is only in relatively recent years that radio-telephony has been applied to railway working on an appreciable scale. Brief references have, however, been made to the employment of radio communication in reports which have been presented on marshalling yard design and practices.

Although no mention was made of radio-telephony in the final summaries adopted at the Eleventh Session, Madrid (May 1930) on Question 10, which dealt with « Methods to be used in Marshalling Yards to control the speed of vehicles being shunted and to ensure they travel on to the lines in the various groups of sidings », a reference to it was made by one of the Reporters on that subject, the late Mr. C. R. Byrom, Chief General Superintendent of the then London Midland and Scottish Railway of Great Britain.

In his Report, which dealt only with railway administration in the specific countries allotted to him, Mr. Byrom stated:

« The use of wireless apparatus does not appear to have developed on any appreciable scale in connection with humping operations either for code ringing or as a means of verbal communication »

and then went on to quote from « Westinghouse International » of February-March, 1929, as under :

« Two locomotives ahead, and three behind, were slowly starting a 131-car train weighing 9 601 tons. The front end had been going two minutes and a quarter before the rear end moved, and a towerman, not realizing that the long string was under way, signalled a light freight train to pass it. The head engines set the emergency air, called for brakes. The three

rear engines, a mile and a quarter away, pushed steadily ahead. A wreck was certain. But the head engineer remembered the newly installed train radio, snatched the transmitter and called the caboose. The three rear engines quit pushing, went into reverse. The 9 601-ton train stretched, stopped, cleared the light freight by a few feet. This happened this year. Similar incidents will occur again, for radio-telephony on trains ceased this year to be experimental. The Chesapeake and Ohio operated with this equipment for a three months' trial period early in the spring. The Pennsylvania made a two months' test in the summer. 1929 will see commercial installations on several roads. »

Thus at an early stage in considering the use of radio for railway purposes, some Administrations felt there was need for means of prompt communication between driver and guard particularly on long freight trains, and the Westinghouse Company in America is understood to have commenced experiments with wireless telephony on freight trains in 1925.

Although radio-telephony did not form the subject of an independent report at the Fifteenth Session held in Rome in 1950, it was alluded to in reports on other subjects. For example :

QUESTION 3. — *New technical methods adopted for the design and construction of large marshalling yards.* (M. MARCHAND, *Special Reporter*.)

« Many Administrations make use of wireless installations to provide communication between the shunters and engine drivers; these are short wave, about 1 m. sets with modulation of the amplitude, and frequency or phase, which can assure one way and two way communications.

» They make it possible to improve the output whilst maintaining more complete and accurate liaison between the staff than optical signals, which have to be multiplied at heavy expense when the shunting makes use of several engines or when there is a large number of sidings in the reception group.

» (Incidentally, it should be noted that the arrangements reported at Madrid for direct control of the shunting engines by the hump staff have not been developed.)

» However, certain Administrations point out :

» — on the one hand, radio apparatus must be of very good manufacture to assure a semi-permanent service without too high maintenance costs;

» — on the other hand, it would be desirable to have moveable equipment, which could be fitted on any locomotive at any time, since lacking this, it is necessary to install fixed sets on all the locomotives likely to be used for shunting in the marshalling yards.

» Portable radio sets are also used to enable the men in the yard to communicate with the men in the posts; in the United States, the details of the composition of trains are listed in certain yards by dictaphones which record the information sent by the markers off by radio. »

The present question is classified under Section III headed « Working » of the Agenda of the London Congress to be held in 1954, and from the wording of the question, it has been assumed that the primary object is to ascertain developments in regard to the application of radio in railway working. In compiling such a report it will be necessary to refer to some of the technicalities of radio equipment, its operation and maintenance, the frequencies allotted and the like, but it is proposed to confine these details to a minimum, whilst at the same time enabling a full appreciation to be gained of what is involved. The subject has been interpreted in its widest sense, and in the course of our report we have not confined ourselves to radio-telephony, but reference is made to other branches of radio which have been, or may be, introduced to facilitate the various activities of a railway.

A common questionnaire was formulated

with the other Reporter on this subject and circulated to the Participating Administrations. A list of the Administrations in the countries allocated to us is given in Appendix A, with an indication as to those which have furnished replies and those from which no response has been received. In the early stages it was noted with some concern that there are now only two railways in the United States of America which are members of the International Railway Congress Association, viz., the Delaware and Hudson Railroad Corporation and the Long Island Railroad, and whilst their contributions would have been welcomed, they, of course, embrace only a comparatively small proportion of the potential sources of information on this subject in the U.S.A. Having regard to the large amount of experimental work undertaken and the extent to which radio has been applied in America — probably greater than anywhere else in the world — it would have presented a severe handicap to us in the production of our report if the experience of the American Railroads were not readily available to us in an authenticated form. As the Association of American Railroads is an organisation affiliated to the International Association, a copy of the questionnaire was sent to that body and we are indebted to the President, Mr. Faricy, for a co-ordinated reply covering the railroads in the United States which has been invaluable to us. We also wish to acknowledge the assistance obtained from articles which have appeared in « Railway Age » and « Railway Signaling and Communications » (U.S.A.) from which we have taken the liberty of quoting, and of reproducing some of the published illustrations.

Systems of communication between fixed locations such as the telephone, telegraph and the teleprinter are so widely used by railways that they have become commonplace and are almost taken for granted. Yet the very nature of the task of the railways deems that communications play an ever increasing part in the urge to provide more efficient and expeditious transportation for passengers and freight. It is this urge which has inspired railways to explore every invention or innovation which might be applied to transport with a view to its adoption if, thereby, safety and efficiency would be improved.

Until recent years, the recognised forms of telecommunications on railways have been those established between fixed locations only, and it is generally accepted that the utilisation of land lines is the most efficient method of communication between fixed points and the least susceptible to transmission difficulties, except in regions where there are peculiar topographical or climatic conditions. However, the running of a railway requires a high degree of co-ordination in the activities of thousands of men at widely separated and continually changing locations. These movements have hitherto been controlled from fixed points, but now that radio-telephony has been made available to the railways in a practical form, it is the intention to examine the uses to which it has been put and its further potentialities.

In doing so, we do not propose, except in special instances, to discuss the question of costs, because it would be difficult to determine a common denominator having regard to the different currencies in the various countries. Apart from this, initial, operating and maintenance costs will, of course, vary considerably, dependent upon the local conditions and the type and size of the installations.

Definitions.

It may assist in the perusal of this report if, at this stage, we set out brief definitions of the terms more commonly used in relation to radio communication.

Alternating currents.

The generation of radio waves depends on the existence in the transmitting apparatus of alternating currents; that is, currents the magnitude of which varies periodically with time, as illustrated graphically in figure 1. It will be noted that the magnitude increases from zero to a maxi-

mum value in one direction, for convenience referred to as the positive direction, after which it returns to zero. It then increases to a maximum value in the opposite or negative direction, returning to zero, and repeating the cycle of operations over and over again.

Amplitude.

The amplitude of an alternating current is the positive or negative maximum or peak-value of that current, as shown in figure 1.

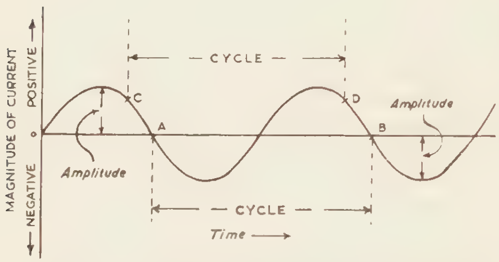


Fig. 1. — Graph of alternating current indicating meaning of amplitude and cycle.

Cycle.

A cycle of an alternating current is one complete cycle of events; for example, from zero to maximum in one direction, and down to zero, then to maximum in the opposite direction and back to zero. Section A B, of the wave train of figure 1 is one cycle, as is also section C D.

Frequency.

The frequency of an alternating current is the number of complete repetitions or cycles in unit time, and is expressed in cycles per second, kilocycles per second or megacycles per second. One kilocycle per second and one megacycle per second are respectively 1 000 and 1 000 000 cycles per second. The frequency units employed are abbreviated as follows :

cycles per second	c/s
kilocycles per second	kc/s
megacycles per second	Mc/s

In some countries the term « hertz » (hz) is used for cycle per second, and also kilohertz (khz) and megahertz (Mhz) for kilocycle and megacycle per second respectively.

Radio waves.

The aerial carrying alternating current generates in space electric and magnetic effects usually referred to as the field of the electric current. The field consists of two parts; firstly, the induction field which decreases rapidly with distance from the aerial, and secondly, the radiation field which decreases less rapidly. Close to the aerial the induction field predominates, but at distances greater than, say 1/6th of a wavelength from the aerial, the important phenomenon is the radiation field which is the electro-magnetic effect made use of in radio.

Propagation of radio waves.

The radiation field referred to above can be looked upon as an electric stress existing in space, the magnitude of this stress varying with time in a similar way to the alternating current in the aerial. This alternating stress travels away from the aerial with a velocity approximately equal to that of light, namely 186 000 miles per second, or 300 000 000 metres per second.

Wavelength.

Owing to the fact that the magnitude of the radiation wave varies periodically with time while it is moving through space,

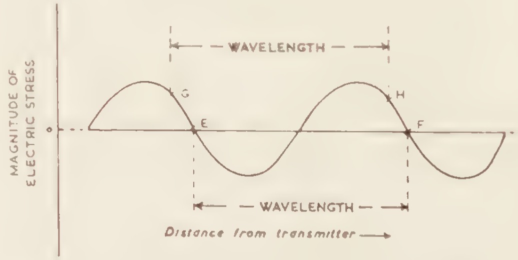


Fig. 2. Graph of radio wave indicating wavelength.

at any instant of time the electric stress representing the radiated wave varies similarly along its direction of travel as is illustrated in figure 2, which shows a graph of the same shape as that of variation of magnitude with time. The distance covered by a single cycle of operations is known as the wavelength and is measured in metres. Hence the distance E F. represents one wavelength as does the distance G H.

Relationship between frequency and wavelength.

The frequency of a radio wave can also be defined as the number of complete cycles which pass a given point in unit time, but it must be understood that the frequency, so defined, is identical with that of the current in the aerial. It follows from this fact that the frequency multiplied by the wavelength is equal to the velocity of propagation of the wave.

Taking the velocity of propagation as 300 000 000 m per second, the following relationships can be utilised to convert frequency to wavelength and vice versa :

kilocycles/sec to metres

$$\left.\begin{array}{l}\text{wavelength}\\ \text{in metres}\end{array}\right\} = \frac{300\,000}{\text{frequency (kc/s)}}$$

megacycles/sec to metres

$$\left.\begin{array}{l}\text{wavelength}\\ \text{in metres}\end{array}\right\} = \frac{300}{\text{frequency (Mc/s)}}$$

metres to kilocycles/sec

$$\left.\begin{array}{l}\text{frequency}\\ \text{in kc/s}\end{array}\right\} = \frac{300\,000}{\text{wavelength (metres)}}$$

metres to megacycles/sec

$$\left.\begin{array}{l}\text{frequency}\\ \text{in Mc/s}\end{array}\right\} = \frac{300}{\text{wavelength (metres)}}$$

Modulation.

Modulation is the super-imposing of the signal, e.g. speech frequencies, on the carrier wave by varying the amplitude, frequency or phase of the carrier wave or by transmitting the carrier wave train in short pulses.

Microwaves.

Microwaves can be defined as waves, the frequency of which is such as to require the use of waveguide or coaxial cable technique. Wavelengths of microwaves are less than about 20 or 30 cm.

Channel.

A channel is a means of one-way communication.

Inductive carrier systems.

Although not strictly employing radio propagation, reference is made herein to systems which employ inductive coupling between a moving train and the rails or line wires parallel to the track, whence the signals are propagated along the rails or wires. In other words, the induction field mentioned in the above definition of radio waves is made use of and not the radiation field as in true radio. As in radio communication, electronic apparatus is employed. The system is aptly demonstrated by a diagram which appeared in a pamphlet issued by the Union Switch and Signal Company of Swissvale, PA., U.S.A. reproduced as figure 3.

Facsimile.

A system of telecommunication for the transmission of fixed images with a view to their reception in a permanent form.

Television.

A system of telecommunication for the transmission of transient images of fixed or moving objects. The link between transmitting and receiving stations can be land line, radio, or a combination of both.

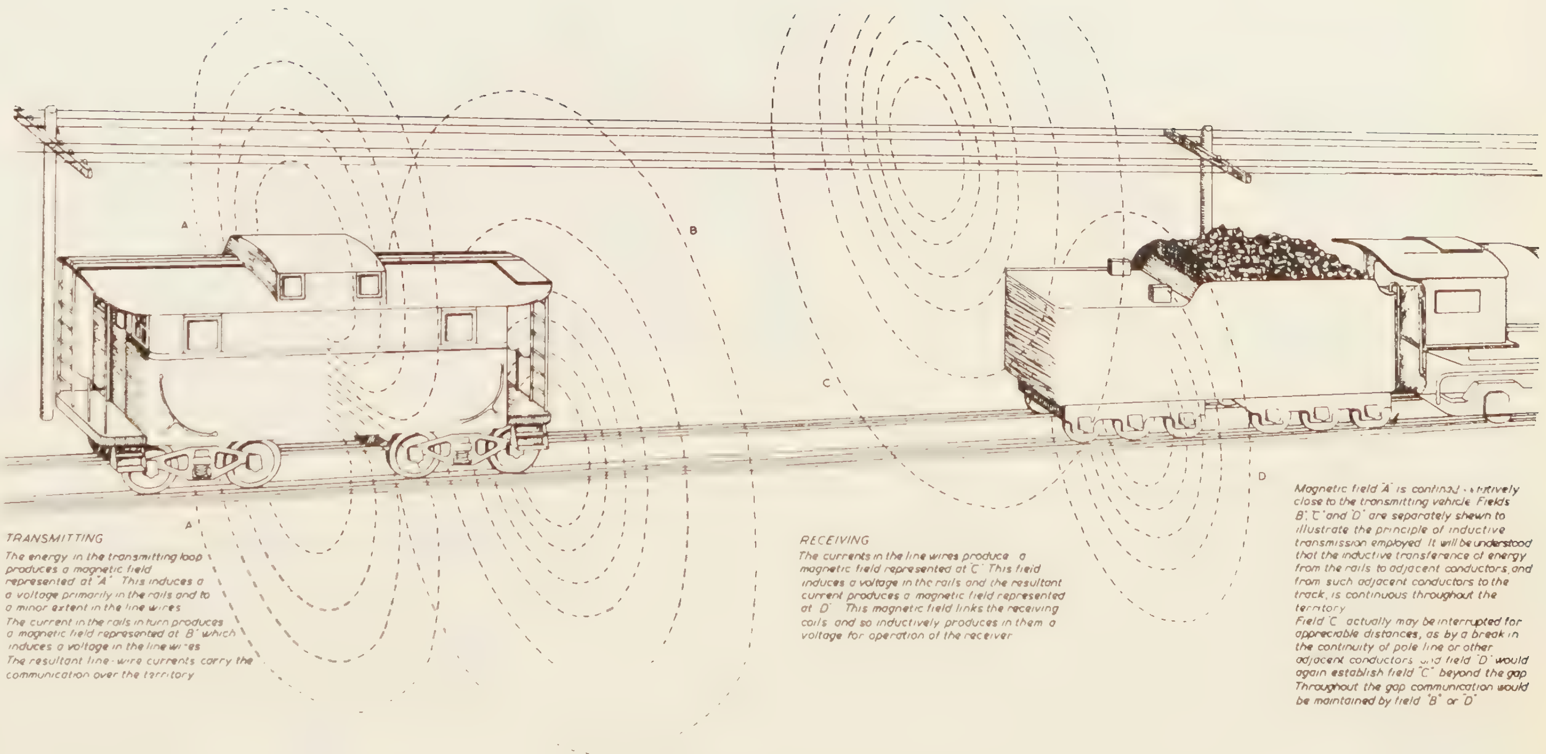


Fig. 3. — Inductive carrier system.

Radiolocation.

Determination of a position or of a direction by means of the properties of radio waves.

Radar.

Radiolocation system where transmission and reception are carried out at the same location and which utilises the reflecting or transmitting properties of objects in order to determine their positions.

Primary radar.

Radar using reflection only.

Secondary radar.

Radar using automatic retransmission on the same or on a different radio frequency.

Development of radiophonic communication.

Although it is little more than half a century since methods of radio transmission and reception have been evolved — MARCONI bridged the Atlantic in 1901, using morse signals for transmission — radio transmission and reception is to-day man's most important means of communication over long distances.

Until about 1915 radio-telephony remained for the experimenter a dream, because practical methods had not been developed for generating suitable radio frequency currents, for modulating them with the weak speech currents and for amplifying the attenuated signals at the receiving end.

These requirements were ultimately met by the thermionic valve or tube, the development of which has involved devoted research and has contributed to the progress of radio communication to an inestimable extent. Each new type of tube, of which there were many, marked a technical advance on some aspect, thus eventually bringing the radio-telephone within the realms of practical accomplishment as it is known to-day.

Research in long-distance radio-telephony was somewhat limited during the first world war, but certain experiments were conducted both in Britain and America. It was not, however, until 1919/20 that the Marconi Company and American interests, both holding patent rights of considerable importance to the future of radio, settled their differences and real progress emerged. About this time, entertainment broadcasting began to develop and soon there were more applicants for permission to establish stations than could be permitted to go on the air. Radio was becoming the hobby of thousands of young men, and the radio lanes were becoming ever more congested. Many new stations came on the air to crowd the existing broadcasters; stations used any frequency or power that suited them, and the trouble grew so rapidly that it was a serious threat to Government and public services. The situation was mitigated to a certain extent by allotting those services the use of wavelengths in the long and medium wavebands and placing the amateurs on the shorter wavelengths which were then regarded as being of little importance. The difficulties continued, however, and by 1927 Governments took a hand, legislation being introduced to regulate the establishment of radio transmitting stations.

Knowledge was growing at this time with regard to the behaviour of radio waves under varying climatic and geographical conditions, including the effect of the sun on transmissions, and intensive research, involving a multiplicity of tests and measurements, was proceeding in order to obtain more information of the factors influencing radio communication.

In both Britain and America the work was pressed forward until, in 1927, the first overseas commercial service was opened between London and New York.

Research continued into the use and development of vacuum tube technology, and by 1929 it can be said that a comprehensive international radio-telephone service was a practical reality.

Wavelengths.

International conferences were held periodically to allocate or re-allocate definite wavelengths for the use of specific countries. This was necessary owing to the limited number of channels available in the long and medium wavebands, which were insufficient to meet essential needs, and preference was naturally given to long-distance radio communication, public broadcast programmes, the requirements of shipping, navies, armies and air forces, and civil aviation. As a consequence the issue of licenses was jealously guarded.

It is recorded that the first approach by the railways of Great Britain to the statutory authority (the Postmaster General) for permission to use radio was made as early as 1922, but a negative reply was received. In fact, before the second world war the use of radio by railways seems to have been discouraged more or less universally, although from time to time and in varying degrees in different countries, the railways were able to carry out experiments in collaboration with manufacturers of radio apparatus.

So far as the railways are concerned, little progress was practicable during the second world war, but under the impetus of war-time inventiveness, rapid advances were made in the development and harnessing of the short waves.

In order to gain an appreciation of these developments and of their importance it is desirable to review the characteristics of waves of various wavelengths and the implications in connection with frequency allocation.

A signal radiated from an aerial is transmitted at all angles of elevation, that part travelling along the surface of the ground being known as the ground wave and the part which travels upwards as the skywave. The skywave will do one of three things. It will pass out into space, or it will be absorbed in the ionised layers which exist in the atmosphere, or it will be reflected back to earth by these layers, depending on the frequency of the wave and on the state of the ionised layers, which are caused by the sun's radiation.

In the daytime, three ionised layers exist, namely the Kennelly-Heavyside, or E layer, and the Appleton layers F1 and F2 which combine at night to form a single layer designated F. Figure 4 shows the approximate position of these layers and also their action on waves of various wavelengths. In general, one may say that the longer wavelengths are reflected by the E layer, and the shorter waves experience reflection from the higher layers; but with further reduction in wavelength, complete penetration of all layers is achieved and the waves are not returned to earth.

Summarising, it can be said that the single night-time F layer reflects waves of frequency up to about 35 Mc/s, the daytime F1 and F2 layers reflect frequencies from about 1.5 to 25 Mc/s and from about 3 to 50 Mc/s respectively, whilst the E layer reflects frequencies from about 100 kc/s to

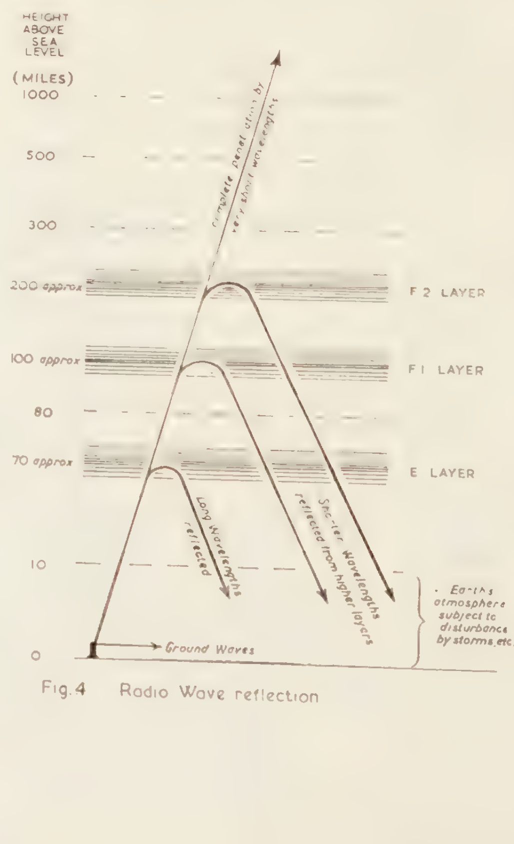


Fig.4 Radio Wave reflection

about 20 Mc/s. These figures are for the most favourable conditions, and the limiting frequencies can vary very considerably. An accurate and detailed treatment of the subject cannot be given in a few sentences and it will be appreciated that this brief generalisation is very incomplete. The state of the ionised layers is very variable and thus stability of communication involving reflected waves is dependent on a careful choice of frequency. Hence different frequencies may be utilised for communication between two points depending on ionospheric conditions.

The ground wave is attenuated as it travels over the earth surface, and if its strength has been reduced below usable values before the first reflected sky wave has reached the earth, there will be a distance over which reception is not possible. This distance between the finish of the groundwave and the reception of the first reflected wave is known as the « skip distance ».

In the case of frequencies above approximately 35 Mc/s, receivable signals are largely dependent upon the direct wave and are regarded as being receivable only on what is termed a « line of sight » basis between transmitting and receiving aerials, thus limiting the range but enabling short distance links to function with reduced danger of interference from adjacent channels.

Entertainment broadcasting represents only a relatively small part of the radio transmission of the world as a whole, and as we know from published frequency allocations, many important radio waves for telephone and telegraph communication operate in all parts of the world right round the clock. On very broad lines, an idea may be obtained from Table 1 of the wavelengths in general use and the purposes they serve.

It will be interesting to consider the importance of the shorter wavelengths from the aspect of frequency allocation. For a given frequency separation, the long wave stations are much more widely spaced in terms of wavelength than are the short wave stations. For ordinary double sideband transmission a total bandwidth of about 8 kc/s, i.e. 4 kc/s on each side of the carrier frequency, would be required for high quality commercial speech, while for high quality broadcasting stations the bandwidth would be much greater. As an example, taking a bandwidth of 8 kc/s, the following table shows the wavelengths covered for three stations in the longwave band :

Carrier frequency	« Published » wavelength	Frequency range covered	Wavelength range covered
192 kc/s.	1563 metres	188-196 kc/s.	1595-1531 metres
200 »	1500 »	196-204 »	1531-1471 »
208 »	1442 »	204-212 »	1471-1416 »

It will be seen that, in the longwave band, the 8 kc/s bandwidth involves a very considerable range of wavelengths. With only three channels a range of 179 m is occupied.

Whilst still employing a bandwidth of 8 kc/s, the table on page 626/12 illustrates that as the wavelengths become shorter the number of channels for a given percentage change of wavelength increases.

TABLE 1

Radio Frequency Spectrum

FREQUENCY		WAVELENGTH		PROPERTIES	TYPICAL APPLICATIONS
Range	Classification	Range	Classification		
Below 30 kc/s	Very low frequency (VLF)	Above 10 000 metres	Myriametric waves	Comparatively low attenuation. Very stable and reliable, day and night and throughout the year.	*10 to 14 kc/s.* Reserved for radio navigation. *14 to 30 kc/s.* Long distance point to point (mainly telegraph).
30 to 300 kc/s	Low frequency (LF)	10 000 to 1 000 metres	Kilometric waves	Rather less reliable at night than VLF. Attenuation in daytime greater than VLF, increasing with frequency — greater seasonable and day to day variation.	Long distance point to point. Mobile (maritime & aeronautical). Radio navigation (maritime and aeronautical). Broadcasting.
300 to 3 000 kc/s	Medium frequency (MF)	1 000 to 100 metres	Hectometric waves	Long distance transmission not as reliable as VLF and LF. Attenuation low during night but high during day — also greater in summer than in winter.	Broadcasting. Medium distance Mobile services and fixed point to point. Radio navigation.
3 to 30 Mc/s	High frequency (HF)	100 to 10 metres	Decametric waves	Transmission over long distances subject to vagaries of the ionised layers in the atmosphere, resulting in very wide range of attenuation, depending on time of day and of year.	All types of medium and long distance, including broadcasting, but mainly excluding radio navigation.

30 to 300 Mc/s	Very high frequency (VHF)	10 to 1 metres	Metric waves	Owing to penetration of the ionised layers by waves of these frequencies, transmission is limited to « line of sight » range except for some increase in range over the horizon due to diffraction. However, diffraction effect decreases with increase of frequency.	Short range communication, fixed and mobile — broadcasting, television and radar, aeronautical radio navigation.
300 to 3 000 Mc/s	Ultra high frequency (UHF)	100 to 10 centimetres	Decimetric waves	Owing to penetration of the ionised layers by waves of these frequencies, transmission is limited to « line of sight » range.	Short range communication, fixed and mobile — broadcasting, television and radar, aeronautical radio navigation. (Long and medium distance communication is achieved by the use of repeater stations).
3 000 to 30 000 Mc/s	Super high frequency (SHF)	10 to 1 centimetres	Centimetric waves	Owing to penetration of the ionised layers by waves of these frequencies, transmission is limited to « line of sight » range. Propagation on the higher frequencies above approximately 10 000 Mc/s may suffer deterioration due to climatic conditions, such as heavy rain or mist. These effects may be apparent to some extent below 10 000 Mc/s, and even as low as 4 000 Mc/s under some circumstances.	Short range communication, fixed and mobile, radio-navigation. (Long and medium distance communication is achieved by use of repeater stations).

Wavelength	Wavelength space required for one channel of communication.	Approximate number of separate channels for which there is room in space represented by a 10 % change of wavelength
15 000 metres	6 250 metres	–
1 500 »	60 »	2
150 »	0.6 »	20
15 »	0.006 »	200
1.5 »	0.00006 »	2 000
0.15 »	0.0000006 »	20 000

It will be seen that the figures in the last column are inversely proportional to wavelength.

It has been recognised by engineers that the utilisation of the waves in the VHF and higher frequency bands is dependent largely on transmitter frequency stability and on the accuracy of receiver tuning, and much progress has been made in this direction. However, it must not be overlooked that, quite apart from frequency stability, the modulation systems employed for VHF and microwave radio often require wider bandwidths than are used on the lower frequency bands.

For reasons of availability of frequency allocations, it will be realised from the foregoing that there is little hope of the railways being allotted the use of channels in the lower frequency bands, and that the future lies in the employment of VHF and possibly microwave radio, the « line of sight » character of which minimises mutual interference and enables the same frequencies to be employed simultaneously in different localities.

The survey of present conditions indicates that the majority of the railway frequency allocations fall into two categories, *a*) the VHF band, say 70/80 Mc/s, and 150/180 Mc/s, and *b*) the higher end of the MF band and lower end of the HF band, i.e. 1.5 to about 15 Mc/s.

To some extent both categories are used for mobile services and point to point communications, but the former category is employed mainly for mobile services and the latter for point to point communication. A small amount of microwave equipment has also been employed for point to point work.

Use of radio between fixed stations.

There are several countries where considerable use is made of wireless for communication between fixed stations over extensive areas. Although these installations are primarily for wireless telegraphy, radio-telephony is utilised as a secondary means of communication in some instances, and it will be of interest to describe the systems and the reasons for their adoption.

Burma.

Before the second world war, communications on the Burma Railways comprised overhead line wires, but these had been damaged to such a great extent, being non-existent in some areas, that after the war it was necessary to resort to radio to re-establish communications.

The outbreak of insurrection which followed the war complicated matters further and made the use of a system more or less impervious to sabotage a vital necessity.

Experiments were, therefore, carried out with radio equipment available locally, which not only proved that satisfactory communication could be established, but that it was a sound financial investment in saving heavy rentals to the Government Telecommunications Department for line wires.

Initially, radio stations were opened at points on the railway which it was considered would be of the most immediate benefit and these were at Katha, Mandalay, Thazi, Pyinmana, Yamethin, Toungoo and Rangoon. The system is being extended to embrace stations further afield and intermediately.

Where power is not available, suitable petrol driven generating sets (output 120 V AC) will be used.

Speech within the range of the sets will be an additional advantage over the former telegraph system.

Radio is in an experimental stage on the Burma Railways and is at present only used to transmit messages. Its success in this sphere may result in its use for other purposes not as yet contemplated.

The following broad estimates of initial and annual costs of installing wireless sets in lieu of the overhead telegraph wire system show a considerable advantage in favour of the former:

i) Capital cost of 50 radio sets complete, including installation charges . . Ks. 5,73.980 (£ 43 045)

ii) Estimated cost of restoration of telegraph instruments . . . . Ks. 67,200 (£ 4 040)

iii) *Comparative statement of annual maintenance and recurring expenses of the two systems.*

RADIO SYSTEM	Kyats	OVERHEAD TELEGRAPH WIRE SYSTEM	Kyats
Contribution to Depreciation Reserve Fund	9 566	Contribution to Depreciation Reserve Fund	1 120
Interest on Capital at 3 ½ %.	20 089	Interest on Capital at 3 ½ % .	2 352
Repairs and replacements of spare parts.	5 000	Maintenance staff and renewal of batteries	61 760
Maintenance staff (Inspector Mechanics) and Running cost of power plant	60 000	Rent payable to Government on Telegraph Lines	124 000
Operational staff	184 320	Operational staff	187 200
Annual Government license fee, etc.	500		
	279 475		376 432

Annual saving by radio system . . . . K. 96,957 (£ 7 272)

Capitalised value of saving at 3 ½ % . . . . K. 27,70,200 (£ 207 765)

East African Railways and Harbours.

This Administration operates 20 fixed and 7 mobile radio installations linking up rail, road and marine depots in Kenya, Uganda and Tanganyika to provide an efficient and reliable means of communication between the three transport systems. A further 5 fixed and 5 mobile stations are to be installed.

This is another instance where an alternative means of communication is desirable because land line connections are costly and difficult to maintain over the type of country across which the lines must run. Where Post Office telephone services exist, these are not 100 % efficient due to land line interruptions and other circumstances outside the control of the Post Office maintenance staff.

The radio equipment is mainly used for the transmission of telegraphic messages between points where either land lines have become congested, or between the three territories where no land line railway communications exist.

Radio-telephony is also employed, the arrangements for this being that each station so equipped is given a fixed time to stand by each morning for discussions to take place. This is necessary because of seasonal changes resulting from solar disturbances which cause deep fading during certain hours of the day, particularly in November and December. Radiophonic communication is carried out before 10.00 h daily and thereafter communication is maintained by wireless telegraphy.

By 09.30 h each morning, headquarters at Nairobi have a complete picture of the traffic position at the main centres. Decisions can then be taken, and orders for their implementation issued immediately, about the movements of lighters on Lake Victoria, distribution of rolling stock and other matters.

Whilst the use of radio-telephony is beneficial in that it ensures the most economical and efficient employment of the Administration's transport resources, it is considered that if efficient « on request » telephone services were provided by the Posts and Telecommunications Administration, consideration would be given to dispensing with radio-telephony, one reason advanced being that it is not private and messages can be « picked up » by the public on commercial receivers. In this event, however, the existing stations would be retained for wireless telegraphy working.

South African Railways.

During the war, a number of short wave telegraph stations were established at the various System headquarters for emergency use in the case of line communications being interrupted. These stations were each of 100 W output power.

Despite their low power and the bad atmospheric conditions prevailing during the summer months in South Africa, they proved extremely useful and were eventually used as an overflow channel to relieve the congestion on the telegraph lines.

It was then decided to increase the power of these stations so that a full-time service under all conditions would be available and at the same time provide a radio-telephone service under emergency conditions for the use of very senior officers only.

Five stations of 1 000 W output were placed in service at Cape Town (Langa), Port Elizabeth (New Brighton), East London (Highgate), Bloemfontein and Johannesburg (Langlaagte). Owing to delivery difficulties during the war, the installation of the equipment was only completed in 1947.

Since that time the station at East London has been closed down. In addition to the 1 000 W stations mentioned there are, 100 W stations at Kimberley, Durban, Windhoek and Kroonstad. The transmitter at Windhoek is to be replaced by a transmitter giving that station an output power of 500 W and also the telephony facility. This station is very important as, during the rainy season, miles of telephone route

are sometimes washed away and the only means of communication is then by radio.

A condition imposed by the Postmaster General of the Union of South Africa is that radio must only be used under emergency conditions.

Finland.

Telecommunications in Finland are largely based on open wire lines, but during the last war the Finnish State Railways used a radio network which covered the whole country and regularly transmitted a considerable part of the telegraphic communications. Their conclusions from the experience gained of departing from the normal means of communication and using radio installations are positive, however, that the maintenance of an extensive radio network in peacetime solely for the purpose of telegraphic communications does not pay.

In the summer of 1952, experiments with the directional wireless system were made between fixed stations at Knopio and Picksämäki operating on frequencies of 77.5 and 87.5 Mc/s, when audibility was maintained during the whole time. Control could not technically be arranged so that absolute level readings could be obtained, but permanent adoption was still pending at the time the return was made, since there was no certainty that communication could be maintained under all and any conditions; for instance if it were snowing, or under changes of moisture and temperature.

Schemes for adopting directional wireless communication between fixed points are, however, being entertained in consequence of the high price of copper wire. A preliminary investigation has been made of the economic aspects of communication by wire and of wireless communication, the main conclusions reached, so far, being that when planning trunk communications, consideration should be given to the possibility of applying directional radio, at least to the extent of calculating the costs of radio. In cases where a new pole line would be required for only a few trunk circuits, the directional radio would probably be more economical.

These general conclusions assume that no difficulty would be experienced in procuring licences for point-to-point communication, there apparently being no such difficulty in Finland.

Further, conditions in regard to the cost of copper wire, the rental or erection costs of buildings for radio stations, the availability and cost of poles, power supplies, etc., would of course vary in different countries and might influence the conclusions elsewhere.

India.

Indian Railways have an extensive network of fixed wireless stations where both telegraphy and telephony are used.

However, the use of radio-telephony is normally restricted to the extent that it is only used when land line channels are not available or are congested.

Wireless on Indian Railways was adopted as a secondary means of communication as it was considered that such communication, especially on long-distance circuits, was more reliable, cheaper and quicker. It was also found that the necessary land wire communication links were not readily made available for railway needs.

The extensive network of wireless telegraphy and telephony covers Railway Headquarters, Divisional and District Headquarters, and other important centres.

Several types of transmitters with power ranging from 20 to 1 500 W are in service, operating on frequencies between 2 and 14 Mc/s. The power of the transmitter is designed in accordance with the type of communication required and the distance involved between the fixed points.

About 200 frequencies are issued for use by the Indian Railways, out of which normally only two frequencies are assigned to each channel, one for day and one for night operation. More important channels are provided with spare frequencies for

use when normal frequencies are found unworkable. Normally very little interference is experienced.

The railways send their requirements for licences to the Railway Board who approach the Posts and Telegraphs Department for their issue. The allotment of the frequencies is regulated by the Frequency Assignment Committee where all major radio user departments are represented.

Indonesia.

In Indonesia, wireless communication is in operation between the head office in Bandung and the District Managers' Offices in Djakarta (100 km), Semarang (120 km), Surabaja (600 km) or Java and Palembang (700 km) on Sumatra. It is used for the despatch of radio telegrams, and telephone conversation if necessary, and no difficulty has been encountered in obtaining licenses.

Radio communication was adopted because land wires were continually being destroyed during the years of the national revolution. It has proved so useful that extension of the system will be considered.

British Railways.

In the congested conditions obtaining in Great Britain, the use of radio communication between fixed points has been discouraged by the Postmaster General and applications for this purpose have not, therefore, been made.

During the second world war, by the special permission of the military and other authorities, a system of wireless communication was established based upon a backbone of fixed stations, with mobile stations mounted on road motor vehicles and sited at convenient geographical centres ready for despatch to places in the area of their location should any important sections be deprived of land line communications. In some areas where accessibility presented difficulties, mobility was secured by installing the wireless sets in rail vehicles.

Frequencies in the medium frequency band were allocated.

The transmission of encyphered messages by telegraphy only was permitted, and although the wireless sets were equipped for speech transmission by radio-telephony, it was laid down by the Postmaster General that radio-telephony should only be resorted to for testing or establishing contact when there was difficulty in exchanging signals in morse telegraphy.

The stations, each with approximately a 50-mile radius, formed a network covering Great Britain, and whilst satisfactory results were obtained utilising telegraphy, reliable telephony was not possible in all cases.

The facilities were only licensed for use as a standby for emergency purposes in the event of a breakdown of land line communication, and when the war was over the licenses were cancelled and the stations dismantled.

Apart from the standby value, having regard to the conditions of transmission imposed, the radio offered no advantages: it was more expensive, slower and less reliable than telephone, telegraph or teleprinter communication by means of overhead or cabled wires.

United States of America.

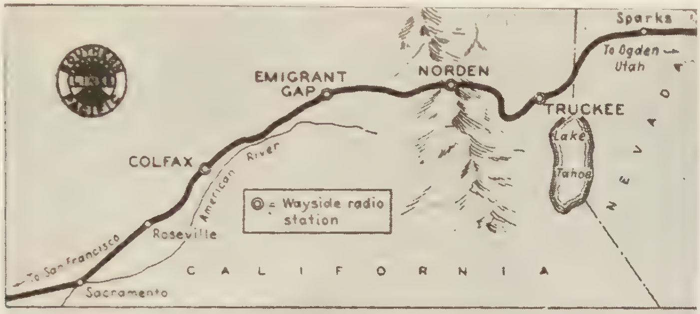
The frequencies allocated for land mobile service in the U.S.A. may not be used for point-to-point communication except on a secondary basis for communication between adjacent base stations, and provided interference is not caused to communications involving radio stations carried on railroad rolling stock.

Radiophonic communication has been used in a number of emergencies when other forms of communication were interrupted due to such occurrences as snow and ice storms, floods, fires, etc. The advantage of such communication lies in the fact that as it consists of radio equipment located at separate points along the railroad, it is less likely to be damaged in emergency conditions, particularly when base stations are equipped with an auxiliary source of primary power. Mobile stations

may also be moved into a stricken area, and emergency point-to-point or point to mobile communication thus established.

The Southern Pacific Railroad provides an interesting example of the utilisation of radio to bridge broken line wires resulting from storms, snow and tempest.

The radio link which has been installed provides a flexible interconnection of the telephone line wire circuit with radio stations at four intermediate offices and on the trains, as well as on snow fighting equipment. If line wires break, the radio can be used from station to station to maintain communication. The system, which incorporates novel features, is on the 155 miles division, which forms part of the overland route between San Francisco and Chicago via Ogden and Omaha, the line from Sacramento, (Cal.) crossing the high Sierra Nevada mountains to Sparks (Nevada) and rising from an elevation of 35 ft. above sea level at Sacramento to the highest point at Norden 6 880 ft. above sea level (see fig. 5). The line passes through the Donner Pass, where heavy snow, sometimes from 10 ft. to 20 ft. in depth, is encountered.



The Southern Pacific's Sierra Nevada line.

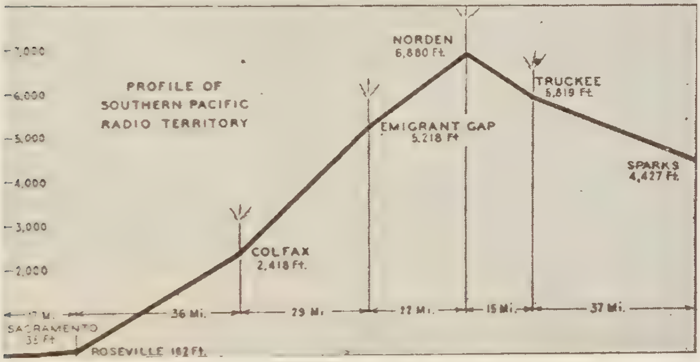


Fig. 5. — The line crossing the Sierra rises in 87 miles from 162 ft. elevation to 6 880 ft.

A conventional two-wire telephone line circuit on a pole line extends from Sacramento through the four offices located at Colfax, Emigrant Gap, Norden and Truckee where radio wayside stations are located, and on to the office at Sparks, which is the east end of the division.

On his desk at Sacramento, the train dispatcher has a small control console which has an enclosed loudspeaker and small toggle-type key levers with associated indication lamps. Voice calls can normally be received over the loudspeaker in the train dispatcher's office from any of the five wayside offices, and he can answer by stepping on a foot treadle when he speaks into his microphone.

Fig. 6. Norden antenna.

In addition, under emergency conditions as may be necessary, facilities have been provided by means of special circuit arrangements, which enable the train dispatcher at Sacramento and trains en-route, to communicate with each other, passing voice messages direct via Norden radio station (fig. 6), Norden hearing the both way conversation, the system returning automatically to normal when the conversation is completed.

Also, at each of the four wayside radio stations the operator's apparatus is normally connected to reproduce voice calls that come in, not only on the line wire circuit, but also by radio from trains within range of the station. The system is so interlinked that if the operator at Norden, for example, wants to talk to the train dispatcher at Sacramento, he pushes his « intercom » button (which prevents his voice from going out on the radio), and then he pushes his press-to-talk button on his microphone when he speaks into it to call the dispatcher. Duplex i.e., « break in » facilities are provided for the dispatcher so that an incoming emergency call can be heard even if he is using the line for another conversation.

This « intercom » method of instantly initiating conversation by voice calling, in either direction, with no delay for the operating of conventional selectors and bells, has proved so important a convenience and time saver, that the previous telephone train dispatching circuit with conventional selectors and calling by ringing, is being left idle.

Normally at each wayside station the radio is in operation to receive calls at all times and the operator can immediately answer. If the operator at Norden, for instance, receives a radio call from a train, he presses the « local » button and pushes the press-to-talk button on the base of his microphone as he speaks into it to answer. When the conversation is completed, the radio system reverts automatically to the normal receiving condition.

An important feature is that if the dispatcher receives no answer to a voice call for an operator at some station, he can send out a special « on-off » control that will ring a bell in the station and then return an « answer back » to give the dispatcher verification of his call.

The area of deepest snow usually extends from 35 miles between Emigrant Gap and Truckee. Snow fighting equipment assigned to this territory includes 14 units. These

units are each equipped with two-way radio tuned to a special frequency to operate only with radio stations at Norden and Emigrant Gap.

Radio equipment is in service on the locomotives used on passenger trains, and installation is being extended to freight locomotives and cabooses.

Modern freight trains may contain 125 cars or more, and the length of such trains will vary from about 1/2 to 1 1/4 miles or over. The locomotive crew at the front end of a train, usually consisting of a driver (engineer), a fireman and a head brakeman, and the remainder of the train crew, usually consisting of a

Fig. 7. — Mobile radio installation in caboose.

conductor and rear brakeman in the caboose at the rear end, have need of intercommunication. Occasion for such intercommunication arises from a number of circumstances. By far the most important of these from the standpoint of safety is general co-ordination of the train operation. As previously indicated, the front end and rear end crews may be separated by over a mile. Trains are under way in both daylight and darkness, in all kinds of weather and over all kinds of terrain. There are many conditions under which visual communication between the front and rear ends of trains is inadequate or

Uses of radio-telephony in railway working.

Great advances have been made in recent years in the application of radio to specific phases of train working, and an account follows of the uses to which it has been put.

(A) **Communication on and with trains en route.**

i) *Between members of a train crew (end-to-end communication).*

Communication between front and rear ends of long freight trains has been widely adopted in the U.S.A.

actually impossible. It is equally true that many occasions arise where the instantaneous communication between the front and rear ends which radio provides can enhance the safety and efficiency of operation. Suppose, for example, a rear trainman observes a hot box, dragging equipment, or dangerously shifted load on his train... if he or the conductor can immediately communicate with the driver, effective action can be taken at once to correct the condition noted and possibly avoid serious consequences which might result if contact with the front end were delayed. If communication with the front end of the train is not possible and the situation too serious to risk delay, the conductor's only alternative is to apply the air brakes from the rear end. If the driver continues to apply power at the front end of the train, the result may well be that the train will break in two — something which is always hazardous.

There are many other instances where end-to-end communication can enhance safety and efficiency of operation. Some of these are :

a) Before starting the train, the conductor may notify the driver when proper train line air pressure has been reached at the rear of the train.

b) When entering or leaving a siding, the driver can be informed as soon as the switch has been cleared by the caboose. Similarly, he may be notified when the rear end of the train has cleared crossovers.

c) Notification of rear flagman's return to the train.

d) General co-ordination of train operation by discussions between driver and conductor. By direct instantaneous radio communication, instructions can be issued and confirmed regarding train movements in bad weather, on curves and under all unfavourable conditions.

The Norwegian State Railways equipped a freight train with end-to-end communication in the autumn of 1952, the reason being the length of trains, as it often happens that when a train stops at a station, the locomotive is already on the nearest curve and not visible from the station.

In no other country from which replies were received is end-to-end communication by radio adopted. Tests have, however, been carried out in Britain which demonstrated that radio communication can be established between engine and brakevan whilst a train is standing or running at low speeds, but difficulty was experienced in the receipt of satisfactory messages on the footplate when running at high speed owing to the noise of the steam locomotive. This disability could undoubtedly be overcome by further experiment with various new types of equipment which come on the market, but so far no conclusive steps have been taken in this direction.

In Britain the longest freight trains are composed of 100 wagons, the total length being approximately 730 yards, but trains of this length are relatively few. A more usual freight train comprises about 70 wagons, locomotive and brakevan, the length being some 520 yards. In either case, the locomotive is practically always within sight and sound of the brakevan, the driver can give indications to the guard by whistle codes, and driver and guard can also exchange hand-signals.

Another factor which has a bearing on the question is the relatively short distances the trains run compared with the U.S.A., and the close proximity of signal boxes where it is the duty of the signalmen to keep close observation on each train as it passes. Defects in rolling stock or loads can thus readily be detected and a train brought to a stand. Further, the incidence of untoward occurrences whilst a train is in motion decreases in ratio to the length of the train and the distances run, and, so far, there has not been sufficient justification for the heavy expenditure which would be involved in the provision of end-to-end radio communication on trains on British Railways.

ii) *Between moving trains.*

Communication between one train and another train or vehicle is carried out on

the U.S.A. railroads on the same frequency as end-to-end communication, since such communication normally would be between trains or vehicles of the same railroad. Such communications might concern numerous matters having to do with the safe and efficient operation of trains: for example, if crews of passing or meeting trains observed dragging or otherwise defective equipment, loads shifted so as to endanger the train or trains on parallel tracks, or obstructions on or near the track or other potential dangers to operation. In any of these conditions effective communications require instantaneous availability of the radio channel to ensure safety of operation. Under certain circumstances, supervisory officials with radio equipped automobiles, or, possibly track cars, may have need of communication directly with trains in their vicinity.

In Malaya where there is a liability to sabotage or attack by rebels, radio communication is used for speech between the driver of the pilot and the driver and the guard of the Mail train following in the same block section. Experiments have also been conducted in connection with the running of two trains in block section with a view to providing visual warning in the cab of the mail train when the pilot has stopped, thus minimising the risk of a collision.

iii) *Between fixed points and trains.*

On U.S. railroads, train movements are under the jurisdiction of train dispatchers. Whilst operators at certain points report the time each train passes these points, radio communication from fixed points to moving trains is utilised to supplement line wire telegraph and telephone communication should it be necessary for any reason to supplement existing instructions or obtain information regarding a train. The object is basically to keep the dispatcher informed as to the location of trains at all times so that he may successfully co-ordinate the movement of trains over his section of the railroad. In addition, there are some communications between moving trains and operators at line side stations involving information regarding train movements, vehicle movements and miscellaneous information which may enhance safety of operation.

Fig. 8. — Basic radio equipment for fixed or mobile use.

If radio communication is to be of greatest value and is to be fully effective in enhancing the safety of train operation, the radio circuit must be instantly available.

On the East African Railways, wireless equipment has been installed in the brake-van of the train working on the Mpanda branch line in south west Tanganyika. The

branch line, which takes off at Kaliuwa 75 miles west of Tabora, runs in a south-westerly direction to Mpanda and is approximately 133 miles in length. No physical land line communication exists on this branch line, the trains being worked under the « one engine in steam » method. Wireless communication has been provided on the train for the purpose of obtaining assistance in the event of an emergency, when communication takes place between the guard of the train and the Station Master at Tabora.

In 1949 experiments were made in Indonesia with radio-telephonic communication between train and fixed stations on the lines Bandung - Tjikampek - Djakarta and Tjikampek - Tjirebon - Tegal, with two auxiliary stations in Padalarang and Purwakarta. The apparatus used was VHF two-way radio equipment, wavelength 4-8 m, power output 25 and 50 W (150 W at the main station in Bandung). The results in level country were satisfactory, but not so good in mountainous districts on account of reflections. The experiments were discontinued owing to budget [illegible].

iv) *Between train and employees on the ground.*

A system also practised in the U.S.A. is the use of radio between a train and employees on the ground which usually involves the employment of portable or pack transmitters. In the event of hot boxes, dragging equipment, shifted loads, etc., it may be necessary for a trainman to inspect cars midway in a long train. In such cases, communication with the conductor or driver, or both, may greatly facilitate the execution of whatever measures are found necessary to correct the trouble, particularly if conditions are such as to render the use of hand or hand-lamp signals unreliable. Similarly, when the rear flagman goes back to protect his train when stopped under conditions in which it may be overtaken by another train, communication with his train or any approaching train may be of value. There are numerous other circumstances where such communication may prove effective in facilitating activities of the train crew and supplementing safety of train operation.

v) *Benefits of train communication.*

The extent to which these systems have been adopted in the U.S.A. will be demonstrated at a later stage in this report.

Many of the benefits of radiophonic communication on and with moving trains are mentioned under the relative headings, but the factors which led to the adoption of this means of communication by U.S. railroads are summed up by the Association of American Railroads in the following terms:

« When used in main line operation, radiophonic communications may be said to supply the « missing link » in the communication system of a railroad; that is, it enables railroad officials at fixed locations to communicate with trains in motion, and of course, it also permits train crews of trains in motion to communicate with such officials, and on long freight trains with the crew members at the opposite end of the train and with other nearby trains. »

(B) **Yard and terminal communication.**

The conduct of operations at marshalling yards and in terminal areas necessitates communication between various individuals, and it is obvious that efficiency and speed of working depends partly upon the character of appliances provided to transmit and receive instructions locally or to engage in essential conversations where the distance is beyond normal vocal range.

Such instructions may take the form of visual signalling, or they may be oral, — the latter by the use of megaphones, telephones, and, in later years, the development of loudspeakers has resulted in this means of efficient communication being introduced at many marshalling yards. Loudspeakers

have greatly facilitated the work of breaking up trains, sorting vehicles, assembling and marshalling them into trains for despatch, together with many incidental internal shunting and locomotive movements.

The usual form of loudspeaker installation at marshalling yards comprises fixed equipment, transmitters and receivers being connected by wires or cables to carry the electrical current, but if the speech can be transmitted and projected with equal volume without the provision of physical connections and is permitted by the licensing authorities, it is apparent that the cost of providing and laying cable routes will be avoided.

Developments in the radio field have advanced to such an extent that, where financial and other conditions permit and new or improved means of internal yard communication are economic, « wireless » is being introduced on a growing scale. It enables verbal communication to be established with or by a person on a moving vehicle, and to or from individuals whose duties require them to be mobile. Answers to the Questionnaire indicate that this is a « fait accompli » and well beyond the experimental stage.

From the point of view of yard operations, the extent of development, or rather application, varies considerably for reasons which will become apparent later.

United States of America.

In so far as the countries allotted to us are concerned, by far the most extensive introduction of radio for yard work has been in the United States of America, where there are many large yards. Under the economic conditions prevailing in that country, an extensive programme of remodelling and modernising existing yards, and creation of new yards either to close existing small inefficient yards or to cater for traffic developments, has been, and is being, carried out. The provision of the most suitable forms of telecommunication for internal purposes, is, of course, only one component in a major undertaking such as the construction and equipping of a modern marshalling yard.

It will perhaps facilitate the descriptions which are to follow if we give below the definition of a yard as prescribed in the Standard Code of Operating Rules in the United States of America, as supplied by the Association of American Railroads :

« A system of tracks within defined limits provided for the making up of trains, storing of cars and other purposes, over which movements not authorised by time table, or by train order, may be made, subject to prescribed signals and rules, or special instructions. »

The definition goes on to say that :

« A terminal is the area in and adjacent to a city — usually large — and normally would include many yards »,

these being circumstances not by any means confined to the U.S.A., and it is obvious that there may be possibilities in utilising radio for communication which extends somewhat beyond the confines of a marshalling yard, unless governmental licensing restrictions or economic and domestic conditions preclude it.

The A.A.R. sub-divide the communication as under :

Between	*and*
Fixed points	locomotives operating within flat or hump yards.
Fixed points	locomotives, transfer trains, tugs, and other vehicles operating within a terminal area.
Fixed point or mobile unit	employees on the ground.
Mobile unit	mobile unit and/or fixed point.

(a) *Between yard tower and yard locomotive.*

At hump yards in the U.S.A. a string of cars being propelled over the hump may and often does number 100 or more, and the speed of propulsion imparted by the locomotive is varied by the engineer (driver) in accordance with instructions received by him from the person in charge at the hump (conductor). It is claimed that the use of radio greatly facilitates the transmission of instructions and makes possible the continuance of humping under conditions of poor visibility, thus reducing delays.

In flat yards where, during shunting, the speed of individual vehicles or cuts of cars is dependent upon the momentum imparted by the shunting locomotive, the person in charge of operations has to issue instructions periodically to engine crews about changing the routing of vehicles and the make-up of trains. Where yard engines are radio-equipped such instructions can advantageously be given by that form of communication (fig. 9).

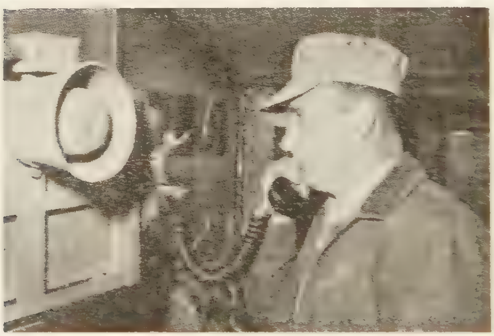


Fig. 9. — Engineman talks to Yardmaster by radio.

(b) *Between yard point and locomotives operating in terminal area.*

In a large terminal area, much switching and transfer operation is necessary. Cars or groups of cars must be moved to and from the spur tracks of manufacturing plants, and from one yard of the terminal to another. By means of radio, switching orders can be transmitted to switch engines promptly, regardless of location, whereas to contact a non-radio-equipped engine it is necessary to telephone yards or manufacturing plants to attempt to relay a message to the crew or wait until a member of the crew reaches some point from which he can contact a telephone (call to the office, etc.). In the event of breakdown or other emergency the engine crew can contact railroad officials immediately. In a harbour area, such as New York, where tugboats are moved to various points to barges, scows and car floats, the tugs handling such movements are immediately contacted by radio for transmission of the same type of instructions and reports as in the case of switch engines. Yardmasters and other railroad officials concerned with operations in a terminal and who travel throughout the area by automobile keep in constant touch with both their offices and switching crews by means of radio.

Below is one example of the application of radio to rail operations in a terminal area.

The Union Railroad performs switching service between other railroads and industries on its 18 mile line around Pittsburgh and there are seven principal industrial switching areas.

At one of these — Rankin there is a radio equipped yard office and six locomotives equipped with two-way radio are in operation within a radius of three or four miles, steel manufacture being the principal industry in the area. The locomotives are used primarily in transfer service, such as hauling ladle cars of hot metal, cars of hot coke, refuse, etc.

Adjustments in the working are often necessary for one reason or another, but by being able to communicate by radio with the switching crews the yardmaster can issue instructions promptly, and delay in locating the whereabouts of the locomotives is avoided.

Another typical example is that of the Atlantic Coast Line installation in the

Jacksonville (Fla.) area. In the north of the city there is a large flat yard with a standing capacity of over 3 000 cars. The yard and terminal area extend for about 15 miles in a north-south direction, and the industrial area is about 10 miles wide. About 300 industries served by the Atlantic Coast Line are located in this area, and cars are interchanged with several other railroads.

A yardmaster located in an office at the centre of Jacksonville yard has direct charge of operations. A Terminal Superintendent has general supervision of yard and terminal operations as a whole and has an office at the yard but spends considerable time in an automobile making trips from one end of the yard to the other and also contacting shippers and switching crews working in the industrial area.

The base radio station is at the Yardmaster's Office. Mobile radio units are in service on ten Diesel-electric switch engines and a radio unit is installed in the automobile used by the Terminal Superintendent (fig. 10).

At the Export Terminals yard in the north-eastern section of the Jacksonville area a second office is maintained from which are directed switching activities among the industries and docks. Another base radio station is installed in this yard office consisting of a transmitter-receiver mounted in a desk-top cabinet, with built in loudspeaker, hand-set, and volume control. The antenna is mounted on a 35 foot sectional mast near the building.

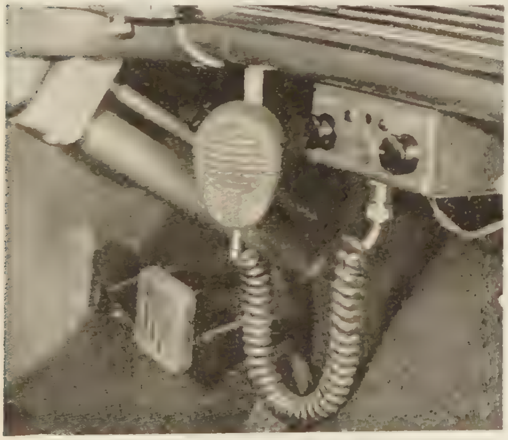


Fig. 10. — Radio apparatus in automobile used by the Terminal Superintendent.

The same carrier frequency is used at Export Terminals yard as at the main Jacksonville yard base station, namely 160.29 Mc/s, so that only single frequency radio equipment is required on switching locomotives, regardless of the yard area in which they may be operating.

c) *Between fixed or mobile units and employees on the ground.*

The usefulness of radio communication between the person in full charge of yard operations, stationed at a fixed point, and engine crews working in the yard as well as employees on various duties often considerable distances away, will be apparent, and many instances exist on U.S.A. railroads of installations providing this ready means of communication.

It is the practice in some cases to fit yard locomotives with duplicate hand sets. These are located near the end of the locomotive at a height where they can be conveniently reached by an employee standing on the ground. In a few installations, a duplicate control box has been fitted on the yard locomotive above the rear footboard so that the radio equipment might be operated by a yard conductor without the necessity for contacting the engineer of the locomotive (fig. 11).

Mobile sets carried by individuals are also used to advantage. Apart from the prompt reporting of bad-order (mechanically defective) cars, increasing use is being made of radio in connection with car-checking. It is necessary for the « consist » of a train, whether conveying cars for destinations on the same railroad or for transfer to another railroad, to be transmitted from one yard or terminal to the next one at which the train has to be broken up or re-marshalled, and this is

done normally by teletype machine — this advance information being essential to reduce terminal delay. When a train is made up, an employee equipped with a pack radio set walks alongside the train and reads off the car initials, numbers, destination, etc., simultaneously transmitting them to the car clerk in the yard office who can repeat it back to check for accuracy. The car clerk either copies the information or arranges the car bills in train order as the information is supplied. This procedure can be completed as fast as a man can walk the length of a train. The waybills can then be given to the outbound conductor with copy of the teletype wheel report for the train departure. Thus radio enables time to be saved and avoids the duplicate recording otherwise necessary.

« Railway Age » of February 2nd, 1953, describes an interesting development by the St. Louis — San Francisco Railroad where, at their Lindenwood and Ewing Avenue yards in St. Louis, « walkie-talkie » portable radio sets are used by car checkers for transmitting car numbers to recording devices in the yard clerk's office (fig. 12).

Fig. 11. — Talk back speaker on engine footboard.

Under this system, which is stated to be proving successful and may be installed elsewhere on the railroad, a car checker is equipped with a portable sending and receiving set, powered by a two-cell wet battery, the transmitter having a power output of a half-watt and a range of approximately one mile. The set is strapped to

the checker's back and a small hand micro phone and ear piece are connected to it. Total weight of the unit is 10-lbs. The checker thus equipped stands at one end of the yard as a train comes in, and calls off numbers on the cars as they pass by. Under the old system he had to wait until the train had stopped, walk the entire length of the train, and write down numbers and letters of each car.

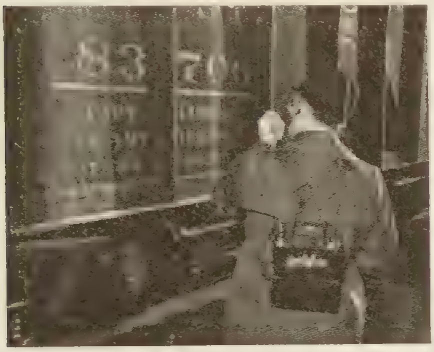


Fig. 12. — Car checker using portable radio.

As he talks, the checker depresses a small button inset at the top of the microphone. This automatically, via radio, actuates a wire recorder (Dictascriber) in the clerk's office and the « consist » of the train is recorded for later transcription.

The base station at each of the two yards operates on a different frequency, to prevent interference. Three portable units, set at the same frequency, are used in conjunction with each station, along with two wire recorders. Thus, if a clerk is busy transcribing from one wire recorder, he can connect his receiver to the other recorder. Batteries in the walkie-talkies sets are recharged after three hours use. Usually, only one or two of these walkie-talkies are in use at any one time, the batteries of the third being on charge.

A recent additional application of radio in the U.S.A. is from the yard office (fixed point) where the car clerk, having received the teletype « consist » of a train from the last yard giving information as to contents, destination, routing and special information such as icing requirements, makes out cards which are tacked on to the cars of a train which has arrived. For various reasons changes are sometimes necessary and if the car carder carries a portable radio pack, he can readily be communicated with from the yard office.

The following synopsis of an article published in « Railway Signaling and Communications » September 1951, is an interesting example of how radio is applied as a component part of yard communications. At the John Sevier yard of the Southern Railway U.S.A., in addition to an extensive party line talk-back loudspeaker system covering the yard area, three-channel radio and light weight portable transmitters are in use.

The seven Diesel locomotives employed are equipped with two-way radio and there is a fixed radio station at the hump. The locomotives are used interchangeably on three different services, and the radio is arranged to operate on any one of three frequencies.

When an engine is pushing cars from the receiving yard over the hump, radio is used between the engineer (driver) and the hump conductor at the hump office. When the land station is not in use for communication, an electronic device causes the radio transmitter to transmit a tone for one-half second at ten-second intervals. These « beeps », heard by the driver on the locomotive, are an indication to him that the radio is in operating condition.

When yard locomotives are used to pull blocks of cars out of the classification (sorting) sidings and assemble them on the departure tracks, the moves are directed by a miniature radio used by the conductor as he walks about the yard directing this work. In order to minimise the weight of these portable sets, they include transmitters only (fig. 13). A land station radio relay repeats the conductor's transmission to the locomotive. Both the conductor's transmissions and those of the engineer

(driver) are amplified and repeated over a public address system so that all members of the crew, including conductor, hear both sides of all conversations.

Car inspection.
Combined radio-loudspeaker system.

« Railway Age », 23 February 1953, describes and illustrates a novel communication system in connection with car inspection developed by the St. Louis-San Francisco Railroad at the Kansas Avenue Yard, Springfield (Mo.).

Fig. 13. Yard Conductor with transmitter.

Each car inspector (examiner) is equipped with a light-weight portable radio transmitter. If he finds a defect in a car he speaks into his microphone and his message is transmitted by radio to a fixed radio receiving station. The message is then reproduced on paging-type loudspeakers, 27 of which are on poles at various locations in the yard and 5 are in offices, including that of the car foreman. It is thus heard by him and by others who may be working on the train or are concerned in other ways.

The car foreman can speak via a microphone on his desk to all the 27 outdoor and the other 4 indoor fixed loudspeakers, and when he has received messages from all the inspectors working on the train giving any further defects or reporting when they have finished, he can prepare the necessary list for the Yardmaster at once.

Heretofore, when an inspector had finished his job he had to walk perhaps half the length of the yard to reach a telephone. Similarly he had previously to walk to the end of a train to set up a blue flag (indicating that a man may be between cars), whereas he now calls to one of the other men near the end of the train to set up the flag and receives confirmation that this has been done. The defect may be one he can remedy himself.

In addition to the advantage of the saving in time and added benefit of the safety feature involved, the inspector (examiner) stationed in the caboose uses his radio in connection with the paging loudspeakers to talk to the man on the locomotive, regardless of length of train, and thus inform the engineer (driver) when the gauge in the caboose indicates the proper pressure for testing the air brakes.

The radio used by each car inspector (examiner) consists of a pocket transmitter enclosed in a canvas pouch, with dry batteries in a second pouch, both being attached to the man's belt with a shoulder strap. A flexible wire extends from the set

to a small palm-type microphone carried normally in the pocket. These small transmitters operate on a frequency separate from other yard radio, and the power output is 0.1 W. The device has been tested to two miles, but a range of one mile is adequate (fig. 14).

Fig. 14. — Car Inspector (examiner).

At a central location in the yard is a tower on which is mounted the antenna (triple-skirt type) for the fixed radio receiver equipment.

The benefits are said to be so important that similar installations are being planned for other yards on the same railroad.

Sweden.

The Swedish State Railways use radio-telephony at one large marshalling yard for the purpose of two-way communication between the switch-master and the drivers of the shunting locomotives.

When cars are being pushed over the hump, better control of speed is obtained, thereby reducing the number of derailments. It replaces manual and optical signals, the range of which is limited under conditions of snow and fog. It is intended to introduce radio-telephony at some other yards.

Finland.

The Finnish State Railways use simple radio installations at two marshalling yards to facilitate working in foggy weather and conditions of poor visibility. A point worthy of mention is (having regard to temperatures in these northern climates) that radio avoids the necessity for the driver of a shunting locomotive to keep his cab windows open to be able to see signals. The far wider range of orders which can be transmitted by wireless is considered a desirable advantage.

The communication is between the engine driver and the yardmaster (supervisor) and/or the shunting guard. The shunting locomotives are temporarily using an American « handie-talkie » packed into a box which can accommodate large batteries.

A programme is planned, however, to include locomotive radio installations for the two yards Riihimäki and Hyvinkää, to work by the intermediary of a fixed station at the first mentioned place which is 12 km distant from the latter.

Great Britain.

There is only one permanent radio installation at any yard on British Railways, i.e., at Whitemoor Up marshalling yard on the Eastern Region. This is a hump yard equipped with retarders and other modern features, and the wireless installation is in regular use between :

Control tower;

Hump foreman's cabin;

Diesel-electric yard shunting locomotives, the latter being equipped with « car type »

radio sets fitted in special metal cabinets (fig. 15).

Radio was introduced at this yard to speed up humping under normal conditions and to obviate delays in bad weather. No previous method has been superseded, and the use of radio supplements semaphore hump signals, giving a finer control over humping speeds. It also saves time compared with other means of communication, i.e. megaphone or loudspeaker, between the yard staff and the crews of the Diesel-electric locomotives.

Experiments have been carried out at yards on certain other Regions of British Railways but, whilst they have proved technically practicable, further permanent installations have not been adopted for a variety of reasons such as the following:

a) Difficulty in justifying the expenditure involved; i.e. in demonstrating a sufficiency of advantages to set off against capital outlay, either in place of existing means of conveying or receiving instructions, or supplementary thereto.

b) With few exceptions, the yards are not so large, and therefore distances not so great in Britain, as in certain other countries where more progress has been made in applying radio-telephony for yard purposes.

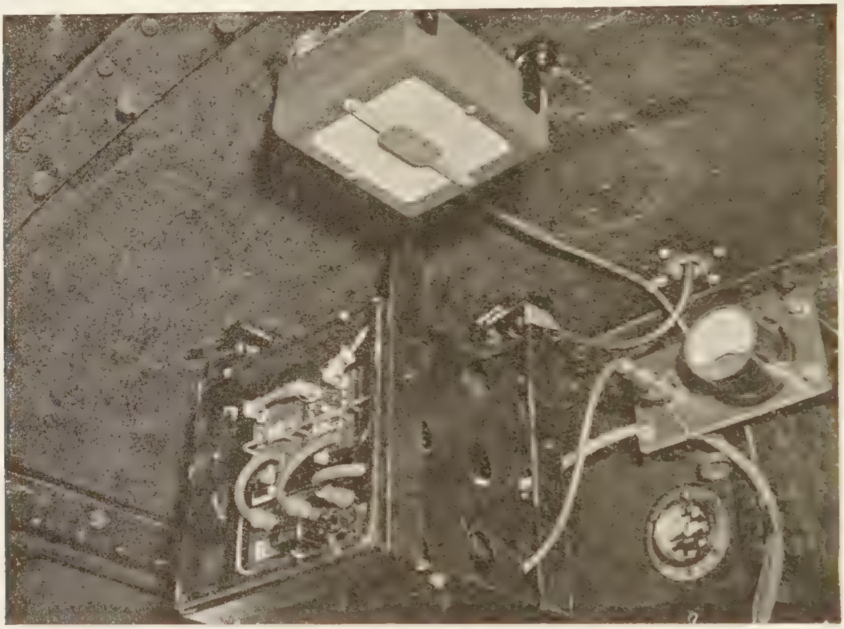


Fig. 15. — Whitemoor. — Apparatus and loudspeaker in engine cab.

c) Certain differences in organisation and control of operations exist in Great Britain as compared with some countries; for example, the work at a large yard is more de-centralised than in the U.S.A. where a high degree of control of detailed operations appears to be concentated at, and exercised from, one central point. The more delegation of responsibility there is, the less need and justification there is for incurring the expense of providing additional means of communication.

d) At the large yard in Britain most

recently modernised, i.e., Toton Up on the London Midland Region, the layout, the unique system of hump signalling (position-light) and the loudspeaker network provided, already give clearly defined and comprehensive facilities.

e) Since it is sometimes economically practicable and desirable at some large yards, and necessary at others, to make use on occasions of locomotives other than those scheduled to work exclusively at the particular yard, unless such locomotives were equipped to receive and transmit wireless messages from and to some supervisory point, it would clearly be impossible to rely upon a radio installation solely.

Resumé of yard and terminal application.

As the greatest developments in this field have taken place in the U.S.A. it is appropriate to quote the fundamental reasons for the adoption of the systems described as expressed by the Association of American Railroads, viz. :

« Instantaneous communication between a yardmaster or terminal superintendent and crews under his direction saves a great amount of lost motion and generally improves the efficiency of yard and terminal operations. »

The Communications Section of the A.A.R. has given much attention to the possibility of developing radio-telephony in general and for yard and terminal purposes in particular. At its Annual (28th) Session held in Quebec in October 1951, the Chairman of the Section stated that : *« The use of radio and developments in the radio field has become the most important single subject in the work of the Section. »*

After pointing out how essential it is under present-day conditions to increase efficiency, speed up traffic and improve railroad operation, particularly by reducing delays in moving freight through yards, and how great strides had already been made in this direction by the building of elevated structures to house the person in charge of yard operations, also providing extensive paging and talk-back loudspeaker systems, he referred to the following specific uses to which radio was now being put extensively :

A) To maintain constant contact between the yard tower and crews on switching locomotives;

B) Between switching foremen and locomotives in hump operation;

C) Between yard conductors working along switching leads and locomotives working in classification and forwarding yards;

D) In checking trains and cars in yards.

If item A) is interpreted as embracing movements in terminal areas — of which examples have already been quoted herein — and which in parlance employed on British Railways are usually known as « local trips », i.e., where locomotives work outside the confines of a marshalling yard when serving private sidings and railway terminal depots in the locality, the existing and potential application of radio-telephony for yard purposes falls into simple categories as under :

a) Between some central supervisory point such as a control or yardmaster's office, and locomotives in the yard or engaged on freight operations in the adjacent area.

b) Between the person in charge of propelling movements over a hump at hump yards and the driver of a locomotive engaged on humping operations.

c) Between foremen or head-shunters and drivers of locomotives engaged on shunting operations (for example, secondary sorting and marshalling) in other parts of the yard.

d) i) to and from wagon examiners, where speed is desirable in reporting defective wagons; and

ii) to and from checkers where detailed recording of the composition of trains is necessary.

(C) Engineering operations.

Whilst engineering work is not « railway working » in the strict sense of the term, it is so closely allied that it will not be out of place to mention some of the uses to which radio has been, or may be, put in this connection.

Engineering operations as applied to railways can be said to embrace :

1) Construction of new lines;

2) Track maintenance;

3) Signal and telecommunications engineering;

4) Clearance of lines due to breakage by accident, storm, fire or similar reasons.

In 1946/47 the East African Railways decided to use fixed wireless stations on the construction and re-alignment of 113 miles of railway track between Nairobi and Nakuru. Six sets of equipment were obtained and placed at intervals of 25 miles on this project. These installations afforded relief to existing communications, rendered is possible for the resident engineer to have immediate and direct radio-telephonic communication with Section Engineers, and were also of considerable use in cases of emergency such as accidents to, and sickness of, staff. Following upon the excellent results achieved, the equipment was subsequently operated successfully on the Western Uganda extension between the resident engineer's headquarters at Kampala and the various section engineers on the line up to Mityana.

The ground to be covered is very rough terrain where practically no communications are in existence.

On engineering operations, radio communication will always be used by the East African Railways on further railway construction projects. It has, by virtue of its efficiency, earned a place as a permanent feature in this sphere.

Radio is also used on construction work in the U.S.A. an example being provided by the Chicago, Rock Island and Pacific Railroad on the construction of a 34-mile section of new single-track main line to replace the Rock Island's existing route between Atlantic (Iowa) and Council Bluffs. This project eliminates about 10 miles of curved track, and will take about two years to complete. The undertaking is divided into three sections, each under the supervision of a resident engineer.

As one of the final phases of the project, a pole line will be constructed on the new right-of-way. In the meantime direct communication was needed urgently in this construction area. Therefore, as a temporary, radio communication facilities were installed for service during the two-year construction period.

Transmitter-receiver base radio stations were installed at the headquarters of the three resident engineers (fig. 16). Auto-

Fig. 16. — [illegible] type antenna tower which can be [illegible] without use of crane.

mobiles used by the three resident engineers and the supervisory construction engineer were equipped with transmitter-receiver radio. In addition, portable « walkie-talkie » sets were provided for inspectors and survey parties.

By means of this radio equipment, calls were made between the offices of the three resident engineers; between these offices and the four automobiles in the respective territories; between the automobiles, within range; and between the portable sets and the fixed or mobile stations, as well as between portable sets. This flexible means of communication was used effectively to co-ordinate the work of the engineering and construction forces. Bridge inspectors used the walkie-talkie sets to maintain hourly contact with one of the fixed stations, or the automobile used by a resident engineer. The portable talkie sets were used by instrumentmen to talk to rodmen to tell them when they had the sights desired or of other movements to be made on long sightings where rodmen might not be certain of hand signals.

As in other applications of radio on railroads, the numerous intangibles proved to be sources of additional savings. These savings, plus those more apparent, arose from the closer co-ordination and utilisation of men, machines and material, and the smoother execution of the project which this modern form of communication provided.

In Great Britain, the London Transport Executive utilise radio for engineering operations, having two radio systems, one for Civil Engineer's work, consisting of a 100-W transmitter working on a frequency of 87.225 Mc/s and communicating with eight road vehicles. This transmitter covers the whole of the London Transport Railway area using amplitude modulation. The vehicles transmit on a frequency of 77.225 Mc/s and their transmission is picked up by any of four fixed receiving stations. The output of these receivers is fed to a Report Centre located at the Signal Department offices, from where the 100-W transmitter is modulated. Three of the vehicles are equipped with breakdown material and one of these is equipped with three hand portable sets for communicating with the vehicle. The remainder of the vehicles are for the use of personnel only.

The other system for use on the Signal Engineer's work consists of a 12-W transmitter and receiver and two 12-W transportable sets with two hand portables which all operate on a frequency of 78.74 Mc/s. This equipment employs amplitude modulation and is regularly used for temporary communications.

The factors leading to the adoption of radio communication by London Transport were :

a) To enable constant contact to be kept between mobile key personnel who by the nature of their duties must be contacted immediately.

b) To enable mobile gangs to be instructed from a central point during engineering works.

A similar service has been introduced by the New South Wales Government Railways, Australia, for the purpose of directing technical staff to faults which occur on their high tension reticulation system. Frequency modulated duplex working is employed, the system comprising several base stations and a number of road motor car and heavy truck installations and forms ready means of communication from the Electrical Trouble Officers to staff working at locations where faults occur. The greatest advantage in the use of this system has been the ability to rectify high tension traction faults with the least possible delay. Traction faults cause traffic delays with a consequent loss in revenue, and the use of radio has resulted in direct economies in this regard. Another advantage is the ability to have a maximum number of staff working on normal maintenance and construction duties, and, at the same time, all such personnel are available for emergencies, so eliminating the need for keeping

fully equipped trucks and skilled staff standing by at depots for emergency purposes only. The benefits are such that this Administration is considering extending the system to Signalling and Communications maintenance services.

A considerable amount of experimental work has been carried out by British Railways in order to assess the value of radio communication in connection with the activities of the Signal and Telecommunication Engineer's Department. Such communication proved to be very useful in the positioning, adjusting and testing of isolated colour light signals, and in the co-ordination of staff engaged in the testing and bringing into use of major signalling schemes.

Benefit was also derived from radio communication during a series of telephone interference tests on an electrified line which involved the simultaneous recording of electrical measurements at widely separated points.

In Denmark, radio-telephony is used in connection with signal engineering operations and maintenance of electric overhead wires; and in Norway, consideration is being given to its adoption between power stations and maintenance staff on the track.

Apart from directing the operations of lifting and similar equipment on track construction and maintenance work, there is evidence of the use in the U.S.A. of radio when clearing the lines in the case of an accident, and for co-ordinating the movements of snow ploughs, etc., when lines are blocked by snow. It is also expected that radio devices might be utilised to warn track gangs of the approach of trains.

(D) Ancilliary services.

There have been occasions, in America, particularly in New York harbour, where railroad tugs have rendered valuable assistance to the Municipal Fire Fighting Forces in connection with pier fires. Prompt dispatch of railroad tugs to such fires is greatly facilitated by the use of radio communication.

As will be appreciated, crowd control in London presents a peculiar problem, especially in connection with special events, Bank Holidays and the like, and the London Transport Executive employ a 15-W transportable set with two hand portables for passenger traffic control purposes. Amplitude modulation at frequencies of 77.275 and 87.275 Mc/s is used.

Cartage control.

Experiments have been carried out by British Railways with the utilisation of radio for cartage control in London, involving one fixed station and three radio equipped road motor cars in which travelling inspectors traverse the district. Communication is generally satisfactory over a range of 15-20 miles, except in certain areas screened by high ground.

Within the area covered, some interference is caused by tree-lined streets, high buildings, and trolley bus wires, but by taking the cars to another spot or pulling into a side street, these difficulties can usually be overcome.

The facilities provided are intended as a quick means of contact between essential mobile staff, and the more important advantages are in conection with :

a) diversion of an inspector to a particular job or in emergency to a place where difficulties have arisen;

b) special messages for attention; and

c) vehicle breakdowns or accidents.

The experiments are continuing with a view to increasing the range by the use of directive aerials at the fixed station. A frequency in the 80 Mc/s range is employed.

Railway police work.

Although information with regard to this particular activity was not specifically sought in the questionnaire, the New South Wales Government Railways Administration has furnished an example of the use made of radio-telephony for police work

in the prevention and detection of thefts from railway vehicles and premises.

The system is controlled by the Railways Investigations Section, and is maintained in continuous use. The service is provided by one base headquarters installation, a number of car installations, and light-weight portable sets carried by members of the staff.

Communication is from a fixed station to mobile, and from mobile to mobile installations. The maximum range is within a radius of 25 miles from the fixed station, the mobile to mobile working being limited to 5 miles.

Frequency modulation is employed on a frequency of 161.26 Mc/s, the base station using a power output of 250 W, and the mobile stations (transmitter-receivers mounted in road motor cars) using a power output of 20 W with simplex channel working. The portable F. M. transmitter-receivers operate on the same frequency (161.26 Mc/s), and employ a power output of 0.3 W derived from dry cells.

The control is located at the headquarters of the Investigation Section within the Sydney city area, being connected by land lines to the main base transmitter located at road level on Sydney Harbour bridge, signals being fed into a wide band aerial mounted on the highest point of the arch, approximately 480′ above sea level, by means of a low loss coaxial pressurised gas filled feeder.

Fixed station receivers, also operating on a frequency of 161.26 Mc/s, are located at strategic points governed by the local terrain, all being connected by land line to the central control.

Statistics indicate that the number of prosecutions instituted after the introduction of the radio communication system has increased greatly, resulting in many more convictions. This in itself has served as a deterrent to others with a consequent falling off in thefts from railway property. It has also been found possible to utilise the detective staff to greater advantage.

Public radio-telephone service to and from trains.

A few railroads in the United States provide a radio-telephone service which enables passengers on moving trains to make or receive a telephone call connected to any point on the public telephone network or with other moving trains so equipped. It is achieved by means of a wireless link from the train to a radio receiving station adjacent to the railway, whence it is connected to the public system, or vice versa.

In America, Telephone Companies which provide the telephone service for the public, established radio base stations for road mobile traffic in urban areas and later extended the system to the highways for the purpose of giving telephone service to motor vehicles moving along the highways. These systems can be used to provide telephone service to trains where the highway system roughly parallels the railroad.

In all cases the train mobile systems for public use are part of the public Telephone Companies' mobile radio telephone systems, and communication to and from trains is with the same base stations of the Telephone Company as are used to communicate with automobiles, etc.

The method of calling is by dial selective calling using tone pulses, and the standard Telephone Company tariffs supply the basis and method of raising charges. The service necessitated the provision of an attendant on each train so equipped to make and receive the calls and collect the charges, but the railroads found the cost of an attendant burdensome. Experiments using coin box operation have been carried out with a view to eliminating the need for an attendant.

The service is provided on important passenger train runs of 4 to 17 h but is not usually available during the entire run because of sections not covered by the existing base stations of the Telephone Companies.

The extent of the demand for the service

in the U.S.A. is limited. The service is generally supplied as a convenience to the public at a financial loss to the railroad.

A train telephone service for passengers requires base-station equipment suitably located along the route of the railroad and a radio channel capable of handling the additional traffic. At the present time neither of these requirements is met for most of the railroad mileage in the United States.

It will have been noted above that the radio base stations used for this service are provided by other than the railroads, and that the base stations also serve other forms of transport, factors which greatly influence the economic aspects. It is doubtful whether similar base stations exist to any appreciable extent outside America, and if a railway considering the adoption of a radio telephone mobile service for passengers had to provide the necessary wayside base stations — even assuming it to be practicable for these to relay signals automatically so avoiding the necessity for continuous attendance — it would be involved in substantial costs which would be difficult to justify unless such base stations served some other purpose connected with the running of the railway.

The practicability of introducing such a service, the methods of charging and the rates to be charged, would have to be negotiated with the authority responsible for the provision of the public telephone service. It is clear that calls must be rather expensive, and justification for the establishment — assuming all other factors to be favourable — of a public radio telephone service to and from trains, can only be determined by commercial expediency in the light of possible demand, which is largely influenced by the distances traversed by the trains.

It is understood that the Canadian National Railways experimented in 1929 with a service of this type, and whilst it functioned reasonably well, it was soon abandoned for economic reasons.

Other uses of radio.

This portion of the report would not be complete unless mention were made of features akin to railway operation in which the principles of radio have been, or might be, applied.

Radar.

The success which has attended the location of objects in the wide open spaces of the air and on the seas, and the part radar played in the last war, has created an impression in the minds of many laymen that the application of radar to railway operation would be an effective panacea for railway accidents.

The problem of the railways in this respect differs greatly from aircraft and ships which operate in media providing comparative freedom from interference from deflecting structures, tunnels, cuttings and the like.

So far as is known, no method has been found to overcome the obvious difficulties in applying radar to trains on the running lines. The chief draw-backs which readily come to mind are :

i) The course of a railway contains many bends, and even if it were absolutely straight and free from tunnels and bridges, the track width would be so small compared with the longitudinal distance involved, that it would not be possible to distinguish between obstructions on the track and wayside objects.

ii) The distance over which the radar signals would be picked up would vary from place to place according to the local conditions which affect propagation at the radio frequencies involved.

iii) It would be difficult to avoid interference from transmitters on trains running on adjoining lines.

iv) The system might be inherently unsafe, as any failure to transmit or receive a signal might indicate clear line ahead.

Some of the objections might be overcome by utilising secondary radar, in which the transmitting signal from the engine would trigger off a signal from apparatus on an obstructing train. However, isolated vehicles might be left on the running line during shunting operations, and it might, therefore, be necessary to fit all vehicles with transmitters to give full protection.

Radio transmissions are utilised in a few marshalling yards in the U.S.A. to determine automatically the speed of freight trains and other rolling stock. This system utilises a form of radar wherein signal reflections from a moving object are used to operate apparatus which gives speed indications in miles per hour. An example of this is at the John Sevier Yard of the Southern Railway, U.S.A., where it is used to measure the speed of rail cars during shunting operations.

This yard is a hump yard equipped with retarders. The control panel from which the retarders are operated has switches which can vary the amount of retardation to be applied. The operator (towerman) judges the speed of the approaching car by sight and sound and he sets for the appropriate retardation before the car approaches. An adaptation of radar indicates in miles per hour the speed of cars when approaching the last retarder in each route (fig. 17).

The speed-measuring equipment, which is a variation of radar originally intended for use by police in checking the speed of automobiles on highways, consists of a radio transmitter which transmits unmodulated 2 455 Mc/s signals continuously. The receiver for the unit is mounted on the same chassis as the transmitter and some of the original signal from the transmitter is picked up by the receiver. While it is important that this signal be picked up by the receiver, direct coupling is not used, normal coupling between adjacent U.H.F. antennas being sufficient. When the signal from the transmitter encounters a metallic object, it is reflected back to the receiver. If the object from which the signal is reflected is moving, « Doppler effects » will cause an increase or decrease in the frequency of the reflected signal. The frequency change in this case is 7.5 c/s per mile per hour. The receiver now has two frequencies impressed on its antenna circuit; they are heterodyned and fed through

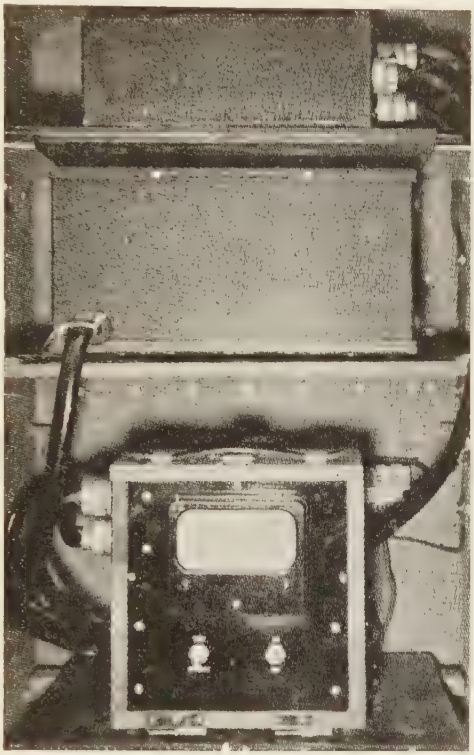


Fig. 17. — Speedmeter device. — Power unit at top, transceiver in middle and meter at bottom.

a frequency sensitive circuit to a meter calibrated in miles per hour. Since the heterodyne signal is the beat frequency of the original and the reflected signal combined, and since change in frequency of the reflected signal is proportional to the speed of the object causing the reflection, the meter reading obtained is a true speed indication, within certain limits.

The antennas for both the transmitter and the receiver are shunt fed twin dipoles with reflectors. The beam, therefore, should be relatively narrow. Consequently experimentation was required before these instruments were properly located and adjusted. As finally located, the transceiver part of each speedmeter is mounted in a weather-proof cast iron housing having flexiglass window for radiation purposes. The housing is mounted on a concrete base, half way between the two final retarders, six feet from the trailing end of the retarder and facing up the hump. The antennas are at approximately track level. Each speedmeter serves two retarders.

The same railroad has recently brought into use at Birmingham (centre of the iron and steel producing district of Alabama) its new Ernest Norris freight classification yard. Here the speed of vehicles through the retarders is also measured by radar devices and indicated visibly in the Control Tower.

There has also been some experimental use in the U.S.A. of radio transmissions for the purpose of transmitting what might be termed telemetering signals. It is contemplated that such installations may be used for indicating the rise of water above a pre-determined level, the actuation of dragging equipment indicators, and so forth.

Apart from the specialised uses described above, no evidence is forthcoming from the countries for which we are reporting that radar has been successfully applied to train working. The situation was aptly summed up by Mr. L. J. PRENDERGAST, Superintendent, Communications, of the Baltimore and Ohio Railroad, when he said in 1946, anent the possibilities of using radar warning devices on railways to avoid collisions (*International Railway Congress Bulletin* dated August 1946) :

« Of course, we have seen so much accomplished that was, at one time, classified as « impossible » that a prediction that this could not be solved would be foolhardy. All I can state is that at present it is not solved nor does an early solution seem probable. »

What was said then seems to be the position to-day.

Facsimile transmission.

Facsimile transmission is a modern method of transmitting over normal communications channels (which may be physical or carrier) an exact copy of black and white written, typed, sketched, printed or photographic material.

The inherent accuracy of facsimile transmission and the uses to which it may be put need not be detailed here, but the system is widely employed by newspapers for the transmission of photographs and is also utilised on some railroads in the U.S.A., based on physical channels.

Facsimile transmission can be accomplished by radio as is demonstrated by the speed with which photographs of events in distant parts of the world are reproduced in the press. Whilst some experiments have been successfully carried out by U. S. railroads on the very high frequencies employed for mobile communication, at the time of compiling this report there were no radio facsimile systems in use. No information is available to us, however, as to why facsimile transmission by radio for railway purposes has not been proceeded with.

Television.

Experiments have recently been carried out in the U.S.A. as to the possible uses of television in railway operation — particularly in yard operation. Television in the generally accepted sense is usually associated with radio, but it should be noted that the equipment employed in the experiments referred to was completely cable connected, although radio transmission can be used in circumstances where the additional expense can be justified and licences are obtainable.

Suitably placed cameras enable the personel in yard offices, without leaving their

APPENDIX « A »

RESPONSE TO QUESTIONNAIRE

Administration	Reply received		No reply received up to 30.6.53.
	Detailed reply	Radiophonic communi-cation not in use	
Argentine	—	—	×
Burma	×	—	—
Brazil (Rio Grande do Sul)	—	—	×
Denmark, State Railways	×	—	—
» Allborg	—	—	×
» Est de Seeland	—	—	×
» Lolland — Falster	—	—	×
Egypt, State Railways	—	×	—
» Delta Light Railways	—	—	×
U.S.A., Association of American Railroads	×	—	—
Finland	×	—	—
Great Britain, British Railways	×	—	—
» » London Transport	×	—	—
East African	×	—	—
Nigerian	—	—	×
South African	×	—	—
Sudan	—	×	—
Rhodesia	—	×	—
Ceylon	—	×	—
India	×	—	—
Malayan	×	—	—
Australia, Victorian	—	—	×
» New South Wales	×	—	—
New Zealand	—	×	—
Iraqi	—	×	—
Iran	—	—	×
Eire	—	×	—
Norway	×	—	—
Indonesia	×	—	—
Sweden, State Railways	×	—	—
» Nora - Bergslags	—	×	—
» Nordmark - Klarälven	—	—	×
» Oxelösund - Flen - Västmanland	—	×	—
» Stockholm - Roslagen	—	—	×

rooms, to carry out duties that normally would require, not only a good deal of walking but also additional wagon movements. Further, instead of a shunter having to walk the full length of an incoming freight train to record the wagon numbers for transmission to the control tower before marshalling commenced, he was able to sit before a television screen which exhibited the numbers one by one as a train moved slowly past a small unattended camera.

The experiments included the inspection of the running gear of wagons, both from points beside and between the rails, and in an engine pit for the examination of a locomotive and tender from below.

Such equipment has obvious limitations in that a television camera cannot reflect anything that is not clearly visible to the camera. A television camera requires a reliable source of constant light, and whilst this could no doubt be provided for specific tasks such as taking wagon numbers during the day or night in localities where atmospheric conditions are generally good, it is difficult to see how the handicaps of fog or falling snow could be overcome.

The amount of power needed to provide the required level of general illumination during hours of darkness render the televising of a general scene (such as approaches to a level crossing) at present a further serious limitation to the use of television.

(To be continued.)

NEW BOOKS AND PUBLICATIONS.

[**385**. 113 (44)]

Activité et Productivité de la S.N.C.F. en 1952. *(The Activities and Productivity of the S.N.C.F. in 1952).* — One brochure (8 1/4 × 10 1/2 in.) of 22 pages with 10 tables. — 1953, Paris, published by the French National Railways.

We often read, especially in the daily papers, criticisms of the working of the railways based solely upon a consideration of the financial results. It is unfair to pass any judgment under these conditions because the fact that the railway is a public service is overlooked together with the resulting burdens upon it and its multiple obligations, which we cannot go into here.

There are other criteria for a more reasonable appreciation of the mission of the railway and the way in which it fulfils it. These are on the one hand the activities of the railway, i.e. the sum total of services rendered, and on the other hand its productivity, which by showing the whole in comparison with the itemised resources gives a true picture of the efforts achieved. These two factors are brought out and commented upon as regards the year 1952 for the S.N.C.F. in this note by the General Manager M. Louis Armand.

The statistics quoted relate to the traffic, available resources (stock and staff), output, consumption, works. Side by side with the figures for 1952 the tables give those for 1951. These are compared with the results for 1938, the first year of the S.N.C.F., and with 1929, the best pre-war year.

Compared with 1951, which was a record year for traffic and productivity, the year 1952 shows a further definite increase in productivity. The essential index figures have increased and the comparison with the years 1938 and 1929 is altogether advantageous.

The note also reports the most striking facts for the year under consideration and organisation measures which have given very good results.

As regards the quality of the service, substantial improvements in the timetables and still greater regularity in running will be noted. Accidents to the staff have decreased very considerably, as well as all railway accidents properly speaking.

The note ends with a brief summing up of the question of the financial results.

E. M.

[**625** .28]

Motive Power for Railways, by C. M. COCK, Presidential address delivered before The Institution of Locomotive Engineers in London, on 24th September 1952. — One brochure (5 1/2 × 8 3/4 in.) of 24 pages, illustrated.

This lecture reviews all the railway traction engines in competition with the steam locomotive. And as the engine is inseparable from the source of power used, it also analyses the conditions under which the natural reserves available can be profited by.

The author has classified the methods of traction other than the steam locomotive under four headings: railcars, electrification, the Diesel-electric locomotive, and the gas turbine locomotive.

As regards railcars, the author points out that important applications have been

made and a large field is open to them in England.

As regards electrification, three systems have been applied : direct current, single phase alternating current, and three phase alternating current. The author gives their characteristics and the success they have met with in different countries. He stresses the various factors that have to be taken into account in choosing the system, and in the case of direct current in particular, the best voltage. Special attention has been given to single phase traction using industrial frequency at 50 cycles, and to the attempts made to use high voltages.

The Diesel-electric locomotive is the subject of a fairly comprehensive report showing what can be learnt from the mechanical possibilities of this competitor of the steam locomotive, comparative costs for oil and coal, and the cost of construction.

The possibilities of the gas turbine are examined, taking into account the special conditions of railway traction.

The various methods of torque converter are compared both from the point of view of the curve showing the tractive effort and the output in terms of the speed.

Very interesting considerations are developed regarding the sources of power available for traction, the consumption and reserves of coal in England, the possibilities of fuelling with petrol, and finally what can be hoped for from atomic energy.

Summing up, the author has tried to define what would be the best tendency for Great Britain. It appears that a large scale extension of electric traction would result in important economic and other advantages and that there is also room for Diesel traction.

E. M.

[**621** .13 (02]

Henschel-Lokomotiv-Taschenbuch *(Henschel pocket locomotive book)*. 1952 edition. — Henschel & Sohn Gmbh., publishers, Kassel, Germany. — Only obtainable from : Deutscher Ingenieur-Verlag Gmbh., Düsseldorf, 10. 384 pages, 349 illustrations & 76 tables (Price : cloth bound, 12 D.M.).

The great German locomotive builders have re-issued this pocket book which appeared for the first time in 1935. As regards locomotive construction, they can plead a long tradition, their experience going back more than a century, without counting other anterior activities. In addition, their plant does not confine itself to building locomotives, but produces all types of railway traction stock. And as evolution has been very rapid in this field during recent decades, and there have been numerous innovations, it will be understood that the book has been enriched by many important additions.

The steam locomotive is still the main preoccupation of the author. Here one can find collected together all the data required for the preliminary elaboration of a new design, as well as the theoretical developments which serve as a basis for the determination of the characteristics and the calculation of the principal components. Detailed descriptions are given of recent improvements to the boiler, the engine, the vehicle.

Amongst the other methods of traction dealt with, in addition to special types of locomotives, are electric traction and the internal combustion engine. The book also includes tables giving the essential dimensions of many locomotives.

A series of photogravures at the end of the volume bring out the most remarkable designs, many of recent date, of this firm.

Without doubt, this manual is intended above all to draw attention to the importance, experience and possibilities of the Henschel plant,. but it is also of documentary and scientific value.

E. M.